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(54) An image processing method and apparatus.

(57) A real time output containing data relating to states of facial parts is generated. A facial area detection unit (11) has monitoring (51-57) and determining (59-61) processing circuits operating in a pipelining manner to determine position of the facial area. The monitoring circuits (51-57) monitor pixel value frequency using 3D histogram and backprojection processing. The generating facial area signal has masks applied by a unit (12) which supplies data to mouth area and eye area detection units (14,15). Each of these operate on similar principles to the facial area detection unit (11).

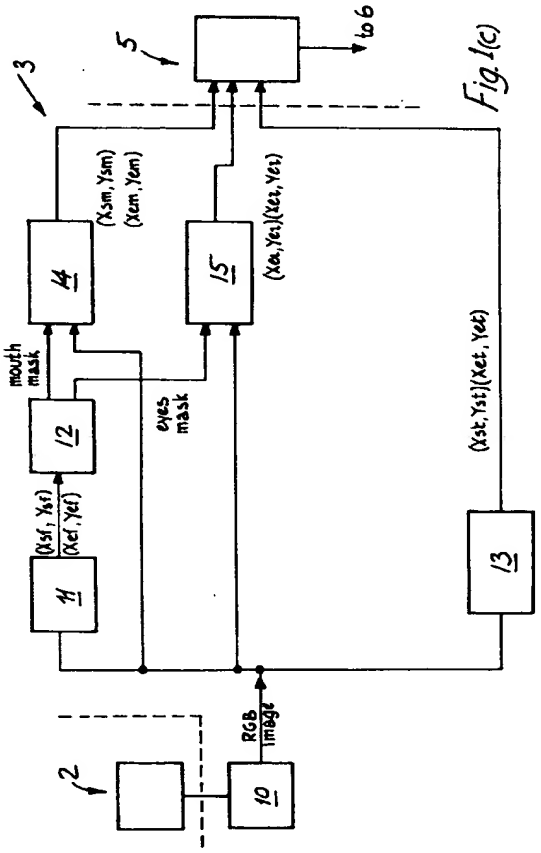

Fig 1(c)

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The invention relates to image processing, and more particularly to processing of images of facial expressions.

European Patent Specification No. EP 474,307A2 (Philips) describes a system having means for receiving facial image data and processing means for processing this data. In more detail, this specification describes a method of tracking an object such as a face. An initial template of the face is formed and a mask outlining the face is extracted. The mask is then divided into a number of sub-templates which are not associated with specific features of the subject. Each successive frame is searched to determine matches. While this method appears to be effective for tracking an overall object such as a face, it does not provide the necessary data relating to state (location, orientation, open/closed status etc.) of parts of the face and other parts such as fingertips. Accordingly, it would appear to have limited applicability not be suitable to such tasks as automatic generation of sign language data and generation displays to assist in understanding and communicating sign language.

An object of the invention is to provide for processing of facial images in real time to identify states of facial parts. Achievement of this objective leads to many useful applications such as sign language recognition, automatic cartoon animation, or improved human-machine interfacing for handicapped people. Another object is to provide for processing of hand images in conjunction with facial images for assistance in sign language understanding and communication, for example.

In this specification, the phrase "sign language" relates to not only what is conventionally referred to as sign language for deaf people but also to recognition of mouth movements to assist in lip reading. The term "recognition" is used in a general manner referring to a broad range of activities including full recognition of sign language to screen display of sign language movements to assist in recognition by the user. Further, the term "colour" is intended to cover all colours including white, black and grey.

The invention is characterised in that:-

said receiving means comprises means for receiving a colour facial image data stream in digital format;

said processing means comprises:-

a plurality of image data processing circuits interconnected for processing the image data in a pipelining manner to provide a real time output, the circuits comprising :-

means for monitoring colour values in the image data to identify image data pixels representing facial parts, and

means for determining states of the facial parts by monitoring positional coordinates of the identified pixels; and the apparatus further comprises:-

an output device for outputting the determined facial part state data in real time.

Preferably, the processing circuits comprise means for monitoring frequency of occurrence of pixel values in the image data.

Preferably, the monitoring means comprises means for carrying out colour histogram matching to monitor frequency of occurrence of pixel values in the image data.

In one embodiment, the monitoring means comprises means for carrying out three-dimensional colour histogram matching to monitor frequency of occurrence of pixel values in the image data.

Preferably the monitoring means further comprises a backprojection means for comparing a generated histogram with a template histogram generated off-line.

In another embodiment, the determining means further comprises a counter for determining the area of the facial part or parts.

Ideally, the apparatus further comprises means for normalising the received colour facial image data stream.

Preferably, the processing circuits comprise :-

a facial area detection unit comprising circuits for carrying out facial area detection operations on the image data; and

a facial part detection unit connected to said facial area detection unit and comprising processing circuits for determining states of a facial part within the detected facial area using the image data and an output signal from said facial area detection unit.

In another embodiment, the apparatus further comprises a mask generating unit connected between the facial area and facial part detection units.

In one embodiment, the apparatus comprises two facial part detection units, namely :-

a mouth area detection unit; and

an eye area detection unit.

Ideally, the apparatus further comprises a mask generating unit connected between the facial area detection unit and the facial part detection units, said mask generating unit unit comprising means for generating an eyes mask signal and a mouth mask signal. In this latter embodiment, the mouth area and eye area detection units are connected in the apparatus to operate on the same image data in parallel.

Ideally, the apparatus further comprises means for carrying out a consistency check to validate determined positional data.

Preferably, each processing unit comprises means for carrying out a consistency check on positional data which it generates.

Preferably, the consistency check means comprises a processor programmed to compare the positional data with reference positional data.

In another embodiment, the monitoring means

comprises means for carrying out binary erosion and binary dilation steps to generate image data in which noise is reduced and the subject area is recovered.

In a further embodiment, the apparatus further comprises image data processing circuits for determining location of a coloured fingertip represented in the input image data.

In one embodiment, the apparatus comprises image processing circuits for facial area and separate image processing circuits for coloured fingertips, said circuits being connected to process the input image data in parallel.

Preferably, the apparatus further comprises a result processor comprising means for receiving facial part and coloured fingertip positional data to generate an output signal representing proximity of a coloured fingertip to facial parts for assistance in communication of sign language.

The apparatus may comprise a video device for generating the image data stream, which may be a camera having an analog to digital convertor.

In another aspect, the invention provides a method of processing facial image data, the method comprising the steps of:

receiving a digital colour image data stream;

monitoring colour values in the image data to identify image data pixels representing facial parts;

determining states of the facial parts by monitoring positional coordinates of the identified pixels, said monitoring and determining steps being carried out by processing circuits interconnected for processing the image data in a pipelining manner; and

outputting in real time a signal representing the determined facial part state data.

In this aspect, the monitoring and determining steps may be carried out to initially identify facial area and position, and subsequently to identify facial parts and determine states of the facial parts.

Preferably, the monitoring step comprises the sub-steps of monitoring frequency of occurrence of pixel values in the image data.

In another embodiment, the monitoring step comprising the sub-steps of carrying out colour histogram matching to monitor frequency of occurrence of pixel values in the image data.

Ideally, the monitoring step comprises the sub-steps of carrying out three-dimensional colour histogram matching to monitor frequency of occurrence of pixel values in the image data.

In another embodiment, the monitoring step comprises the sub-steps of carrying out three-dimensional colour histogram matching in which there is backprojection with comparison of a generated three-dimensional colour histogram with a template histogram generated off-line.

The invention will be more clearly understood from the following description of some embodiments thereof, given by way of example only with reference to the accompanying drawings, in which :-

Figs. 1(a), 1(b) and 1(c) are outline views of an image processing system of the invention;

Fig. 2(a) is an overview flow chart of a method carried out by the system and Fig. 2(b) is a table showing processing parameters in the flow chart;

Figs. 3(a), (b) and (c) are diagrams illustrating normalisation of a captured RGB image;

Fig. 4 is a flow diagram showing facial area detection steps and processing parameters;

Figs. 5 to 9 inclusive are block diagrams showing a facial area detection unit of the system;

Figs. 10 to 21 inclusive are diagrams showing in more detail the manner in which the steps of Fig. 2(a) for facial area detection are carried out;

Fig. 22 is a flow diagram showing coloured fingertip detection steps;

Figs. 23(a) and 23(b) are block diagrams of a unit for coloured fingertip and mouth area detection;

Figs. 24 and 25 are diagrams showing some coloured fingertip detection steps in detail;

Fig. 26 and Figs. 27(a) and (b) are block diagrams showing a unit for generation of facial part masks;

Figs. 28 and 29 are diagrams showing facial part mask detection and input image masking steps in detail;

Fig. 30 is a flow diagram showing mouth area detection steps;

Figs. 31(a) and (b) are flow diagrams showing eye area detection steps;

Figs. 32(a), (b), (c) and 33 are block diagrams showing a unit for eye area detection;

Figs. 34 to 37 are diagrams showing eye area detection steps in more detail;

Fig. 38 is a schematic diagram showing a communications support system of the invention to help deaf people to lip read, and Fig. 39 is a flow diagram showing operation of this system; and

Fig. 40 is a schematic diagram showing a machine interface for lip reading and Fig. 41 is a flow diagram showing operation of this system.

Referring to the drawings, and initially to Figs. 1(a), 1(b) and 1(c), there is shown an image processing system 1 of the invention. The system 1 comprises a video camera 2 connected to an image processing device 3 controlling a video screen 4. The device 3 is connected to a workstation 5 having processing circuits to assist in decision-making in the system 1. The primary purpose of the system 1 is to monitor movement of facial parts and to provide information on the proximity of a person's fingertips to facial parts. These are important aspects of sign language. A sample screen display 6 is shown in Fig. 1(a). Fig. 1(b) shows an effective arrangement for the camera 2 whereby it is mounted on a frame 7 next to a light source 8 at a lower level than the subject's face and is directed upwardly in the direction of the line A. This ensures that the face is always in the field of view,

even when the subject's head has been lowered.

The system 1 operates to identify facial parts and fingertips and determines states for them according to their locations, orientation, open/shut status etc.. This data is generated in real time and the system 1 is therefore useful for such applications as :-

(a) sign language recognition, where the positional relationship of the fingertip to facial feature helps to determine the sign gesture,

(b) automatic cartoon animation, where cartoon characters can be generated in real-time using the results of the identification to give realistic facial gestures, and

(c) human-machine interfacing, where the facial part movement such as that of the eyes can be used to control a screen cursor, and where the movement of the mouth could be used to act as a switch, for use in applications where the user only has control of facial part movements.

Referring now to Fig. 1(c) in particular, the general construction of the system 1 is illustrated. The camera 2 is connected to the device 3 at a normalisation unit 10 which is for elimination of noise caused by the ambient illumination conditions. An RGB image is outputted by the normalisation circuit 10 to a sub-system comprising units 11 and 12 for detection of facial area and for generation of facial part masks. The normalisation unit 10 also delivers RGB image input signals to a fingertip detection unit 13.

The facial part mask unit 12 is connected to provide masking data to both a mouth area detection unit 14 and an eye area detection unit 15. The units 13, 14, and 15 are all connected at their outputs to the workstation 5 which automatically interprets sign language signal content of the received data. The output signal may be used as desired, according to the particular application.

Before describing construction and operation of the system 1 in detail, important functional aspects are now briefly described. The input is a stream of digital colour (in this case RGB) image data and this is processed by the circuits in the various units in a pipelining manner i.e. successive operations are carried out on one or more data streams, individual operations being relatively simple. Processing in this manner helps to achieve real time processing. Accordingly, the output data may be used very effectively for a number of applications, some of which are outlined above.

Another important aspect is that the major units in the device 3 each include circuits which fall into two main categories, namely monitoring and determining circuits. The monitoring circuits monitor the colour values of the image data stream (and more particularly, pixel value frequencies) to identify subjects, while the determining circuits use this data to determine position and area data for the subjects. For the unit 11 the subject is the facial area generally, for the unit 13 a coloured fingertip, for the unit 14 the mouth area, and for the unit 15 the eyes. In other embodiments, there is only facial area and mouth area detection, however the underlying technical features remain the same. The arrangement of units providing general followed by specific subject image data processing also helps to reduce complexity and achieve real time processing. Another important feature is provision of mask data between the general and specific subsequent processing, in this embodiment generated by the unit 12. This improves efficiency of subsequent processing.

Instead of a camera, the primary image signal may be provided by any suitable video device such as a video tape player. The digital image data may alternatively received from an external source, which may be remote.

Referring now to Figs. 2 - 37 operation of the system 1 is now described in detail. The overall method of operation is illustrated in flow chart format in Fig. 2(a) and 2(b).

In step 20 of the method, the next frame image is captured by writing an analog pixel stream in the camera 2 between synchronisation pulses to an image memory via an A/D converter within the camera 2. This provides the initial digital input RGB image signal.

In step 21, normalisation takes place. This involves inputting the captured RGB image to a large look-up table in SRAM as illustrated in Fig. 3(a) and generating a normalised RGB signal image by translation of the RGB value of each pixel according to the formulae of Fig. 3(b) or Fig. 3(c). The look-up table is pre-coded with coefficients for translation of the RGB values. The coefficients of the lookup table are calculated using either of two functions given in Figs. 3(b) and 3(c). The 24 bit RGB image data is made of up of three 8 bit values, one representing R, one representing G, and one representing B. These three values are combined for one 24 bit address into the look-up table. Using the formulae, it is possible to calculate new 8 bit values representing Normalised R, Normalised G, and Normalised B. These three 8 bit data values are combined to form a single 24 bit data signal which is outputted as the Normalised RGB image. The coefficients are precoded into the table and down-loaded into the coefficients during initialisation to the SRAM 10. Alternatively, they may be pre-coded by programming the coefficients into a PROM at time of manufacture.

Where it is desired to use less memory a more complex circuit having a number of smaller look-up tables having discrete logic could be used, whereby processing is broken down into several steps. This arrangement requires less memory but provides a lower resolution.

In step 22 the facial area of the captured image is detected by the unit 11. Step 22 is illustrated in

more detail in Fig. 4 in which the steps 22(a) to 22(n) are shown and processing parameters are indicated. The facial area detection unit 11 is shown in more detail in Fig. 5. The unit 11 comprises a 3D histogram and backprojection circuit 51 connected to a smoothing #1 circuit 52. The former circuit is shown in detail in Fig. 6, the latter in Fig. 7(a).

Operation of the circuit 51 can be divided into three phases of operation, namely X, Y and Z. The operation is as follows.

Phase X

The input image is routed via a multiplexor (MUX) to a memory (MEM) which is used to store an Image Colour Histogram. The pixel values are used as an address to lookup a histogram value which is loaded in a COUNTER. The counter is then incremented to indicate that another pixel whose value is within this histogram box has been encountered, and then this value is re-written back into the Image Colour Histogram memory. This process is repeated until all pixels in the input image have been processed. A histogram of the pixel values now resides in the Image Colour Histogram memory. It should be noted that this memory must be initialized to zero at the start of each frame.

Phase Y

In this phase an Internal Addr Gen is used to provide a memory address to the Image Colour Histogram memory and a Model Colour Histogram memory. The Model Colour Histogram is loaded with a histogram of the model colour off-line, using a workstation to down-load the values into memory. The multiplexor is set so that the Internal Addr Gen impinges upon the Image Colour Histogram. The Internal Addr Gen generates address for all of the histogram boxes and simultaneously the value for the Image Colour Histogram and the Model Colour Histogram are output to the Divider Unit. The Divider Unit, which can be either an ALU or a LUT, divides these two numbers and stores the result in a Ratio Colour Histogram memory. The address for the Ratio Colour Histogram memory is also supplied by the Internal Addr Gen via another multiplexor (MUX). The process continues until all boxes in the histogram have been processed.

Phase Z

In this phase the address to the Ratio Colour Histogram memory is supplied by the pixel values in the original input image, using the multiplexor. The input image is used to lookup the ratio histogram values and output these values to the next processing stage.

A histogram circuit 54 (shown in detail in Fig. 7(b)) and a threshold circuit 53 (shown in detail in Fig. 7(c)) are connected to a binary erosion circuit 55 (see Fig. 8(a)). The unit 11 further comprises a binary dilation circuit 56 similar to the binary erosion circuit 55, and a binary dilation circuit • 57 (see Fig. 8(b)) There is also a projection X-Y circuit 59 (see Fig. 9). Finally, the unit 11 comprises a counter 60 and an ALU 61. The signal flows between these circuits are illustrated in Fig. 5, in which the binary erosion circuit is shown twice for conformity with the signal flows.

The normalised input image signal has R, G and B components, the position in the data stream representing the x, y position. The RGB image signal is inputted to the circuit 51 and the RGB data is separated as shown in Fig. 10 into its R, G and B components. Using the component values, a histogram of colour space is derived by incrementing the particular box the RGB values point too. The function of the 3D histogram is to indicate the relative frequency that one part of the 3D space occupied in relation to another part of the same 3D space. In this example the 3D space represents RGB colour space, with the value (0,0,0) indicating black, and (255,255,255) indicating white. If the input image was only white, and the Bucket size is set to 1, then all boxes except (0,0,0) will be zero. The function of the variable Bucket Size is to allow a group of similar colours to be represented by a single box. This reduces the number of boxes in the 3D histogram and therefore reduces the complexity of the implementation.

After all pixels in the input image are processed, the box in the histogram which has the highest value represents the colour (or colours, if the box in the histogram covers more than a single, discrete colour) which occur most frequently in the input image. The second highest value represents the second most frequent colour, and so on. In backprojection as shown in Fig. 11 the resulting histogram is then compared with a template histogram of the facial part which is to be identified to provide an output BP signal which indicates the degree of possibility that the pixel is in the facial area. A 3D colour histogram of the mouth template is calculated off-line. The resulting histogram represents the frequency of colours within the template image. Those boxes which have colours which are highly representative of the mouth have high values, whilst those boxes which contain no representative contain zero. By dividing the template histogram value by the resulting histogram value in those boxes where the template histogram value is greater than the resulting histogram value, and by dividing the resulting histogram value by the template histogram value in those boxes where the template histogram value is less than the resulting histogram value, a new ratio histogram can be formed which indicates which colours in the input image are likely to belong to the mouth. Finally by using the input RGB image as a look-up address into this ratio histogram, an output image can be formed which highlights those pixels which are most likely to belong to the

mouth.

The next step (also carried out by the circuit 51) is reduction of the image size by sub-sampling the pixel stream to reduce complexity of processing as shown in detail in Fig. 12. This step involves the circuit 51 carrying out sum and average operations on the input image.

The circuit 52 then carries out smoothing operations as shown in Fig. 13 to reduce noise and increase the reliability of the correct threshold function. This involves convolution in which there is multiplication by weights and summation. In more detail, the function of the circuit 52 is to obtain an average value over a group of pixels, whose central pixel is used as the reference pixel. In the simplest case, all pixels are summed and then divided by the number of pixels. This is equivalent to multiplying all pixels by a coefficient of 1 and then summing. However, there are a multitude of smoothing algorithms where the unitary coefficients can be replaced with weight coefficients so that pixels closest to the reference pixel have greater influence on the result than those further away. Figure 13 shows some typical examples.

Operation of the circuit 52 can be explained in the following way. The input image enters the circuit shown in Fig. 7(a) at the beginning of the 256 bit shift register. If the correlation surface is N x M, then there are M 256 bit shift registers and N delay elements in each row. The function of each delay element is to simply store a pixel value for 1 clock cycle and then pass it to the next day elements. Each output from the delay elements is multiplied by a Constant, which are loaded into circuit 52 off-line using the workstation. The results from all of these multiplications are then summed before being outputted.

The circuits 54 and 53 (shown in Fig. 7(b) and 7(c)) then generate a histogram as shown in Fig. 14 to obtain the threshold, the output being a set of values of frequency against pixel values as shown in Fig. 15. There is then thresholding in the area (Xs,Ys), (Xe,Ye) to generate a binary BP image as shown in Fig. 16. The sub-script "s" represents start, "e" representing end. As Fig. 14 shows, the function of the circuit 54 is to build a histogram of the pixel values, with the most commonly occurring pixel value having the highest frequency. An implementation is shown in Fig. 7(b) where the pixel value is used as an address to an SRAM to look-up the number of times the pixel value has occurred. This value is then loaded into a counter where it is incremented and then written back into the SRAM. After all pixels have been inputted into the circuit 54 and histogram values calculated, the histogram values are read into an ALU (Arithmetic Logic Unit) in the circuit 54 where a threshold value is calculated. In the circuit 54, the ALU is used to search for the maximum value by reading every histogram value in the SRAM. When the maximum value has been found it is then multiplied by a constant, usually less than 1, to produce a threshold value which is outputted to the next processing stage.

The circuit 53, shown in Fig. 7 (c) takes as input the pixel stream and using a comparator compares each pixel against the threshold calculated in the circuit 54. If the pixel value is greater than or equal to the threshold the comparator outputs a 1, else 0. In this fashion, a binary image is formed.

The circuit 55 then carries out binary erosion as shown in Fig. 17 to eliminate random noise from the image data. This is followed by binary dilation as shown in Figs. 18(a) and 18(b) to recover the area size. These steps are followed by a further binary erosion step as shown diagrammatically in Fig. 5.

The circuit 59 then carries out projection operations to generate projection X and projection Y values for the facial area as shown in Fig. 19 to obtain the position of the final area edges. A projection search is then carried out by the ALU 61 to check representation of the pixels after binary erosion to generate location coordinates (Xsf,Ysf) (Xef,Yef) the sub-scripts indicating the coordinates of a box in which the face is located in the image.

Finally, area counting by the counter 60 as shown in detail in Fig. 21 takes place to generate a value for the area of the face. This signal is outputted to the unit 12. The data which is outputted includes the area where the face is to be found in the image.

Referring again to the overall flow chart of Fig. 2, a consistency check 23 is carried out by the ALU 60 whereby the position and area values generated in the facial area detection step 22 are monitored for consistency and an accept or reject signal is generated. The criteria used is the area of the identified box. If the area of the box is zero or very small (of the order of only several pixels) this indicates that no face was found in the image. In this event, there is no need to proceed with any additional processing with this frame and therefore the next frame can be processed.

In step 24 the detected area is displayed and this appears in a square box on the screen 4.

In step 25 there is coloured fingertip detection, the sub-steps 25 (a) to 25 (m) being illustrated in detail in Fig. 22. The input is the normalised RGB image and the output is a set of position and area values, as with the facial area detection step 22.

The unit 13 to implement these steps is shown in Fig. 23(a) in which parts similar to those described with reference to Fig. 5 are identified by the same reference numerals. The unit 13 is similar to the mouth area detection unit 14, and indeed the relevant inputs are both indicated, the separate RGB image inputs being indicated by interrupted lines. The unit 13 has an additional smoothing #2 circuit 62, illustrated in Fig. 23(a) and which operates as shown in Fig. 24. There is an additional input to the histogram circuit 54 from an ALU 63 to restrict the area which the histo-

gram is made from. Smoothing #2 and the additional input to the histogram circuit 54 may not be required if quality of the data input is high.

The smoothing shown in Fig. 24 involves averaging an area of pixels around a central reference pixel. All smoothing coefficients are unitary, which amounts to all pixels within the specified area being summed and then divided by the number of pixels. The purpose of this step is to help identify a single location where the fingertip is situated. If smoothing was not performed, then it is possible that there would be several pixels which have the maximum value, determined as shown in Fig. 25. It is then difficult to decide which pixel is the true position of the fingertip. By smoothing, an average of the pixels in a given area can be obtained. The position when the fingertip is located will have many pixels in close proximity to one another with high values, whereas areas where the fingertip is not located may have a few high value pixels sparcely separated. After averaging with the smoothing filter, the area of fingertip is enhanced and it is easier to locate to true position of the fingertip.

A consistency check is carried out by the ALU 61 in step 26 for acceptance or rejection of the generated position and area data for the coloured fingertips. The detected area is displayed in step 27. A tip area check is carried out in step 28 to determine if the area of the fingertip is within a set tolerance At + At-. If the tip area check is positive, a flag TFLAG is set to 1 in step 29, otherwise it is set to 0.

The unit 12 then operates to detect a facial part mask in step 30. The unit 12 is shown in more detail in Figs. 26, 27(a) and 27(b) and the manner in which this step is carried out is illustrated in Fig. 28. This step involves generation of position masks for the mouth and for the eyes using the detected facial area data. Samples of the generated masks are shown at the bottom of Fig. 28. Step 31 involves masking the input image using the normalised RGB image, the mouth mask and the eyes mask as shown in Fig. 29. These masks restrict the area to search for the mouth and eyes to increase the recognition rate. The mask data is fed into the units 14 and 15.

The hardware for the mask generation is shown in Fig. 27 (a). The input into the component 65 is the Skin Area Box, (Xsf, Ysf, Xef, Yef). Essentially the Mouth Area and Eye Area are found by splitting this box into two equal regions so that the Eye Area is specified by the box (Xsf, Ysf, Xef, (Ysf + Yef)/2), and the Mouth Area is specified by the box (Xsf, (Ysf + Yef)/2, Xef, Yef).

Fig. 27 (b) shows the next stage of processing. The inputs to the component 66 are either the Mouth Area or the Eye Area parameters, which are stored in X1, X2, Y1 and Y2. The combination of counters, comparators and adder produce a pixel address stream which defines the box area in the context of the original image. By using this pixel address as the address to the original image, memory, it is possible to only process that part of the image which is defined as being either Eye Area or Mouth Area, as these pixels which are read from the image memory and passed to other image processing tasks. this technique is advantageous since only the pixels which are within the defined areas are processed by the post image processing hardware and not the whole image, and hence this is faster. Also shown is a multiplexor (MUX) and the Image Pixel Stream which is used to load the original image into the memory at each frame.

Position and area data for the mouth area is generated by the unit 14 in step 32 as shown in Fig. 30. The following sub-steps are involved : -

(a) histogram
(b) backprojection
(c) smoothing #2
(d) max. value search
(e) smoothing #1
(f) histogram
(g) threshold value search
(h) threshold of image
(i) binary erosion
(j) binary dilation
(k) projection X & Y
(l) projection search, and
(m) area counting.

The unit 14 which carries out these tasks is shown in Fig. 23(a) and (b) and the sub-steps, being previously described for facial and fingertip detection, will be readily understood from the above description. Of course, a difference is that a masked image is used. An output signal representing mouth area and position is generated.

In step 33, there is eye area detection by the unit 15 and reference is made to Figs. 31 to 37. The sub-steps involved are outlined in Figs. 31(a) and 31(b) and the unit 15 is shown in detail in Figs. 32(a), 32(b), 32(c) and 33. The unit 15 comprises an AND gate 70 for reception of the eyes mask and RGB image data. A transformation circuit 71 is connected to the gate 70, and is in turn connected to a multi-template matching circuit 72. The circuit 71 is an SRAM look-up table. The multi-template matching circuit 72 comprises a set of matching circuits 75 connected to a comparator 76, in turn connected to a smoothing #2 circuit 77 similar to that previously described. Further, there are first and second ALU's 78 and 79 connected to a set constant circuit 80. A template matching circuit 75 is shown in detail Fig. 33.

In operation, the main inputs are the eye mask data from the unit 12 and the normalised input image from the unit 10, the purpose being to determine the eye positions. After the signals are processed by an AND gate, an SRAM 71 averages and divides by three to give a grey scale value as shown in Fig. 34. The multi-template matching circuit 72 determines the best match for each eye as shown in Figs. 35 to

37, a comparator selecting the closest match. The image is smoothed to determine peak intensities for the eyes by two ALU's. A constant is set to ensure that here is no repetition in determining peaks. The circuit 75 for multi-template matching is an 8 x 8 correlator as illustrated in Fig. 33. In this circuit, the sub-script e1 represents the first eye, e2 the second eye.

In step 34 a consistency check is carried out to ensure that the general locations of the detected areas are consistent with the general face layout. In step 35 the detected area is displayed.

A decision is then made by the workstation 5 to determine the nearest facial part to the fingertip in step 37, provided the flag TFLAG has been set to one as indicated by the decision step 36. The result is then displayed in step 38 and this involves display of the relevant part in a different colour within a square box. The process ends in step 39.

Another aspect to the invention is shown in Figs 38 and 39 whereby the system acts as a communications support system comprising a TV camera 100, an image processing device 101 and a workstation 102 with a video screen 103. The image processing device 101 and the workstation 102 carry out the process steps 110 to 120 shown in Fig. 39. Basically, this system involves use of a sub-set of the circuits shown in the relevant previous drawings. The steps include capture of the next frame image in step 110 followed by normalisation in step 111 and facial area detection in step 112. In step 113 a consistency check is carried out and the system proceeds to step 114 involving display of the detected area if the consistency check output is positive. In step 115 there is detection of the facial part mask and the input image is masked in step 116 for mouth area detection 117. After a consistency check 118, the detected areas displayed in step 119 and the method ends in step 120.

It will be appreciated that the communication support system shown in Fig. 38 allows a TV camera to pick up the facial image of a non-deaf person and provides for the generation of a facial image to detect the location of the mouth and its area. This information is transmitted to the workstation 102 which displays the mouth image after the image is magnified. This greatly facilitates lip reading by a deaf person.

A still further aspect of the invention is now described with reference to Figs. 40 and 41. A system 130 comprises a TV camera 131, an image processing device 132, a workstation 133 and a video screen 134. The purpose of the system 130 is to provide for the inputting of machine commands by silent lip movement. The TV camera 131 picks up the user's facial image and the device 132 processes the image to detect the location of the mouth and its area in real time. Using this information, the device recognises the word (command) and this is transmitted to the workstation 133. The workstation 133 is controlled by this command to generate a display as shown on the video screen 134. Operation of the device 132, is described in Fig. 41 and it involves capture of the next frame image in step 140, normalisation, 141 and facial area detection 142. There is a consistency check 143 and the detected area is displayed in step 144. Step 145 involves detection of the facial part mask and the input image is masked in step 146 for mouth area detection 147. After a consistency check 148, the detected area is displayed in step 149 and in step 150 the positional area inputs are matched with templates for generation of a command.

Claims

1. An image processing apparatus (1) comprising means for receiving facial image data, and processing means for processing the facial image data, characterised in that,

   said receiving means (10) comprises means for receiving a colour facial image data stream in digital format;

   said processing means (3) comprises:-

   a plurality of image data processing circuits (11-15) interconnected for processing the image data in a pipelining manner to provide a real time output, the circuits comprising :-

   means (51-57) for monitoring colour values in the image data to identify image data pixels representing facial parts, and

   means (59-61) for determining states of the facial parts by monitoring positional coordinates of the identified pixels; and the apparatus (1) further comprises:-

   an output device (6) for outputting the determined facial part state data in real time.

2. An apparatus as claimed in claim 1 wherein the monitoring means (51-57) comprises means for monitoring frequency of occurrence of pixel values in the image data.

3. An apparatus as claimed in claim 1 wherein the monitoring means (51-54) comprises means for carrying out colour histogram matching to monitor frequency of occurrence of pixel values in the image data.

4. An apparatus as claimed in claim 2 wherein the monitoring means (51) comprises means for carrying out three-dimensional colour histogram matching to monitor frequency of occurrence of pixel values in the image data.

5. An apparatus as claimed in claim 3 wherein the monitoring means further comprises a backprojection means (51) for comparing a generated histogram with a template histogram generated

off-line.

6. An apparatus as claimed in claim 1 wherein the determining means further comprises a counter (60) for determining the area of the facial part or parts.

7. An apparatus as claimed in claim 1 further comprising means (10) for normalising the received colour facial image data stream.

8. An apparatus as claimed in claim 1 wherein the processing circuits comprise :-

a facial area detection unit (11) comprising circuits for carrying out facial area detection operations on the image data; and

a facial part detection unit (14, 15) connected to said facial area detection unit and comprising processing circuits for determining states of a facial part within the detected facial area using the image data and an output signal from said facial area detection unit.

9. An apparatus as claimed in claim 8 further comprising a mask generating unit (12) connected between the facial area and facial part detection units.

10. An apparatus as claimed in claim 8 comprising two facial part detection units, namely :-

a mouth area detection unit (14); and

an eye area detection unit (15).

11. An apparatus as claimed in claim 10 wherein the apparatus further comprises a mask generating unit (12) connected between the facial area detection unit (11) and the facial part detection units, (14, 15) said mask generating unit unit (12) comprising means for generating an eyes mask signal and a mouth mask signal.

12. An apparatus as claimed in claim 10 wherein the mouth area and eye area detection units (14, 15) are connected in the apparatus to operate on the same image data in parallel.

13. An apparatus as claimed in claim 1, wherein the apparatus further comprises means (61) for carrying out a consistency check to validate determined positional data.

14. An apparatus as claimed in claims 8 to 13 wherein each processing unit comprises means (61) for carrying out a consistency check on positional data which it generates.

15. An apparatus as claimed in claim 13 wherein the consistency check means comprises a processor (61) programmed to compare the positional data with reference positional data.

16. An apparatus as claimed in claim 1 wherein the monitoring means comprises means (55, 56, 57) for carrying out binary erosion and binary dilation steps to generate image data in which noise is reduced and the subject area is recovered.

17. An apparatus as claimed in claim 1 further comprising image data processing circuits (13) for determining location of a coloured fingertip represented in the input image data.

18. An apparatus as claimed in claim 1 comprising image processing circuits (11-15) for facial area and separate image processing circuits (13) for coloured fingertips, said circuits being connected to process the input image data in parallel.

19. An apparatus as claimed in claim 17 further comprising a result processor (5) comprising means for receiving facial part and coloured fingertip positional data to generate an output signal representing proximity of a coloured fingertip to facial parts for assistance in communication of sign language.

20. An apparatus as claimed in claim 1 further comprising a video device (2) for generating the image data stream.

21. An apparatus as claimed in claim 20, wherein the video device is a camera (2) having an analog to digital converter.

22. An apparatus as claimed in claim 20 wherein the video device is a camera (2), and the camera is mounted on a frame (7) adjacent a light source (8) so that it is directed upwardly at an angle so that the face of a person seated next to the frame is within the field of view.

23. A method of processing facial image data, the method comprising the steps of:

receiving (20) a digital colour image data stream;

monitoring (22) colour values in the image data to identify image data pixels representing facial parts;

determining (22) states of the facial parts by monitoring positional coordinates of the identified pixels, said monitoring and determining steps being carried out by processing circuits interconnected for processing the image data in a pipelining manner; and

outputting (38) in real time a signal representing the determined facial part state data.

24. A method as claimed in claim 23, wherein the monitoring and determining steps are carried out to initially identify facial area (22) and position, and subsequently to identify facial parts and determine states of the facial parts.

25. A method as claimed in claim 23 wherein the monitoring step comprises the sub-steps (22(a)-22(g)) of monitoring frequency of occurrence of pixel values in the image data.

26. A method as claimed in claim 23 wherein the monitoring step comprising the sub-steps of carrying out colour histogram matching (22(a)) to monitor frequency of occurrence of pixel values in the image data.

27. A method as claimed in claim 23 wherein the monitoring step comprises the sub-steps of carrying out three-dimensional colour histogram matching to monitor frequency of occurrence of pixel values in the image data.

28. A method as claimed in claim 23 wherein the monitoring step comprises the sub-steps of carrying out three-dimensional colour histogram matching in which there is backprojection (22(b)) with comparison of a generated three-dimensional colour histogram with a template histogram generated off-line.

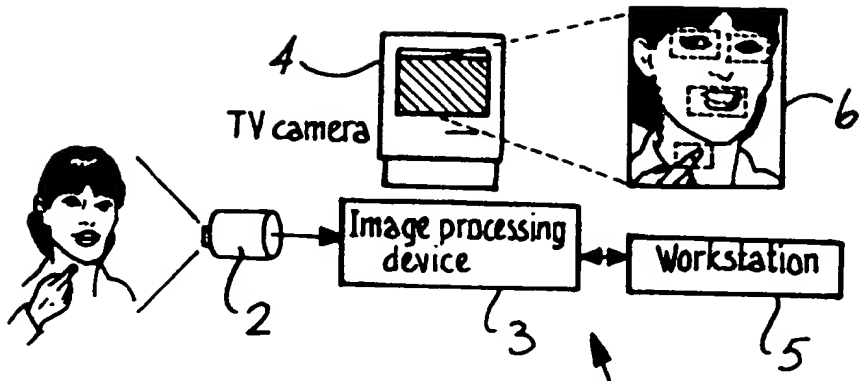

4
TV camera
6
Image processing device
Workstation
2
3
5

Fig.1(a)

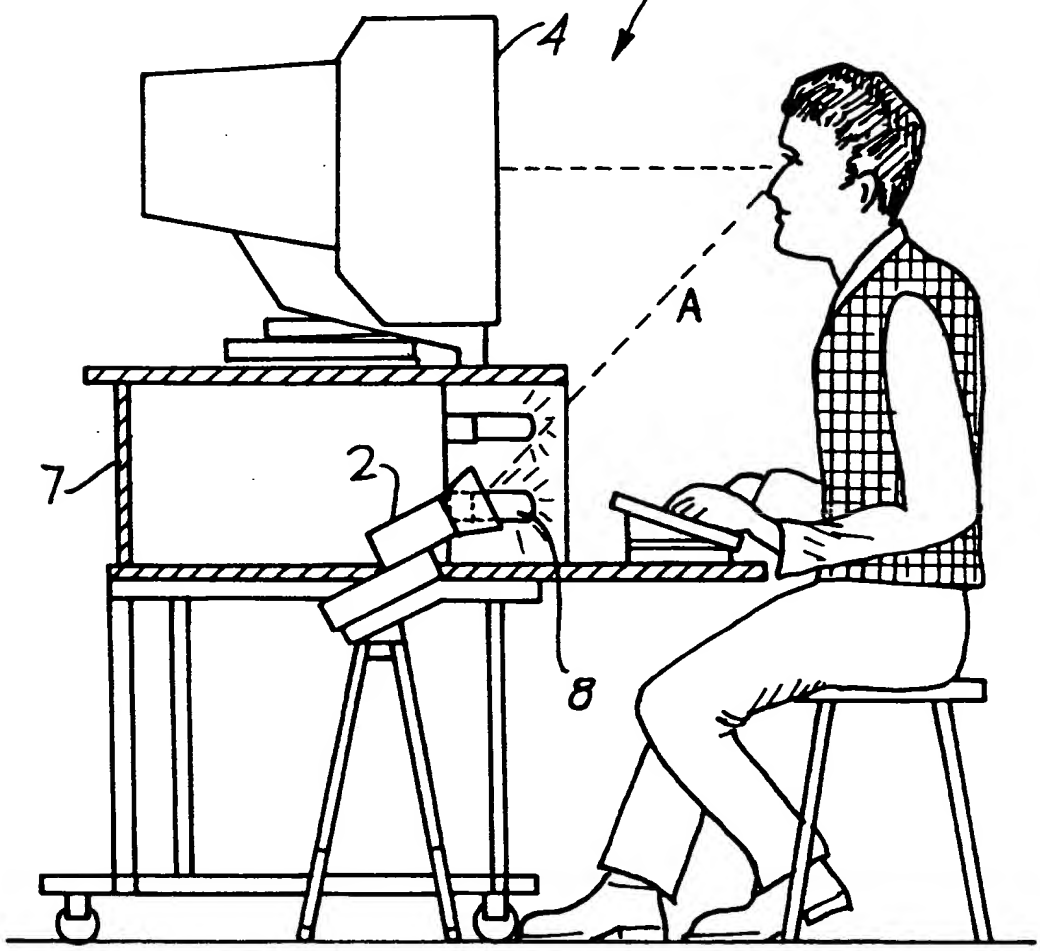

1
4
A
7
2
8

Fig.1(b)

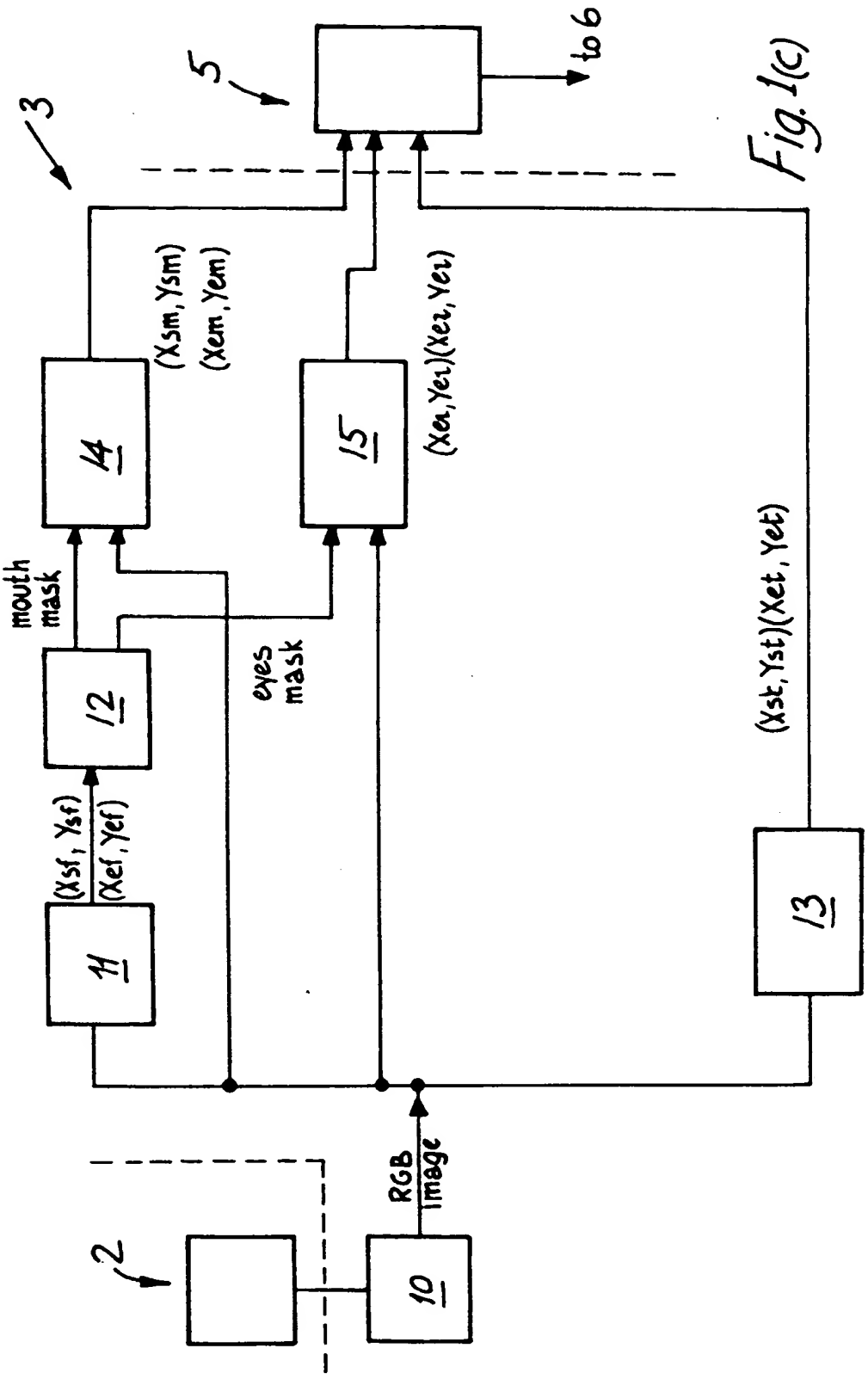

3
5
to 6
(Xsm, Ysm)
(Xem, Yem)
(Xea, Yea)(Xer, Yer)
14
15
mouth mask
eyes mask
12
(Xsf, Ysf)
(Xef, Yef)
11
13
(Xst, Yst)(Xet, Yet)
RGB image
2
10

Fig. 1(c)

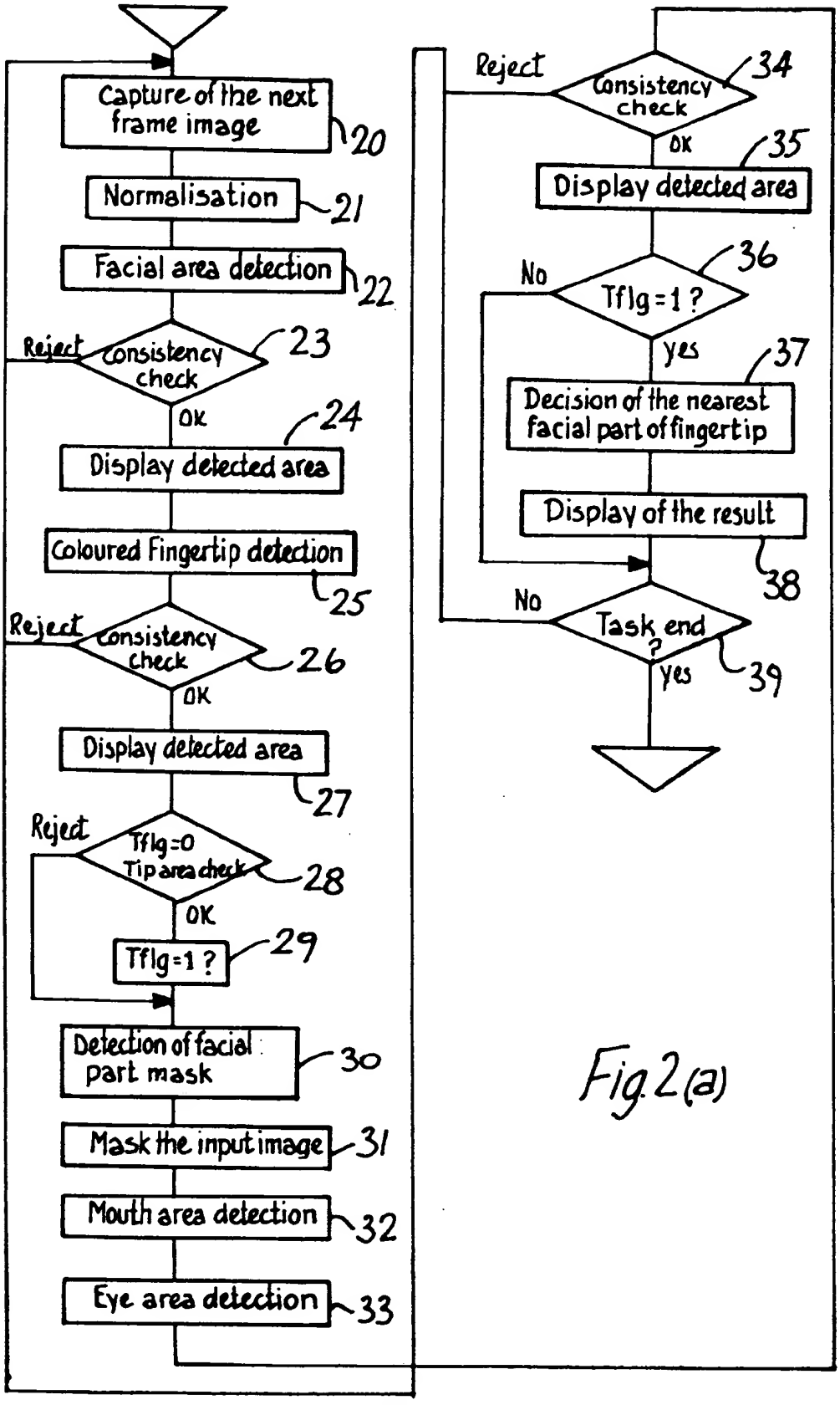

Capture of the next frame image
20
Normalisation
21
Facial area detection
22
Reject
Consistency check
23
OK
Display detected area
24
Coloured Fingertip detection
25
Reject
Consistency check
26
OK
Display detected area
27
Reject
Tflg=0 Tip area check
28
OK
Tflg=1 ?
29
Detection of facial part mask
30
Mask the input image
31
Mouth area detection
32
Eye area detection
33
Reject
Consistency check
34
OK
Display detected area
35
No
Tflg=1 ?
36
yes
Decision of the nearest facial part of fingertip
37
Display of the result
38
No
Task end ?
39
yes

Fig. 2(a)

Processing name	Input	Output	
Capture of the next frame image		Input RGB image	20
Normalisation	Input RGB image	RGB image	21
Facial area detection	RGB image	Position: (Xf, Yf, Wf, Hf) Area: Af	22
Consistency Check	Position: (Xf, Yf, Wf, Hf) Area: Af	Ok / Reject	23
Display detected area	Position: (Xf, Yf, Wf, Hf)	Square box on monitor	24
Coloured Fingertip detection	RGB image	Position: (Xt, Yt, Wt, Ht) Area: At	25
Consistency Check	Position: (Xt, Yt, Wt, Ht) Area: At	Ok / Reject	26
Display detected area	Position: (Xt, Yt, Wt, Ht)	Square box	27
Tip area check	At At+, At-: constant	If At+ <At< At- then Tflg=1 else Tflg=0	28
Detection of facial part mask	BFimage	MouthMask EyesMask	30
Mask the input image	RGB image MouthMask EyesMask	MRGB image ERGB image	31
Mouth area detection	MRGB image Histogram template	Position: (Xm, Ym, Wm, Hm) Area: Am	32
Eye area detection	ERGB image	Position: (Xe1, Ye1) Position: (Xe2, Ye2)	33
Consistency Check	Position: (Xm, Ym, Wm, Hm) Area: Am Position: (Xe1, Ye1) Position: (Xe2, Ye2)	Ok / Reject	34
Display detected area	Position: (Xm, Ym, Wm, Hm) Position: (Xe, Ye, We, He)	Square box Square box	35
Decision of the nearest facial part of fingertip	Position: (Xm, Ym, Wm, Hm) Position: (Xt, Yt, Wt, Ht) Position: (Xe1, Ye1) Position: (Xe2, Ye2)	Decision result	37
Display of the result	Decision result	Square box with the different colou	38

Fig. 2(b)

Fig. 3(a)

1. Input: Input RGB image
2. Output: (Normalised) RGB image
3. Function: Translation of RGB value of each pixel according to the following formula. New R(i, j)= 255* R(i, j)2 / (R(i, j)2+ G(i, j)2+ B(i, j)2) New G(i, j)= 255* G(i, j)2 / (R(i, j)2+ G(i, j)2+ B(i, j)2) New B(i, j)= 255* B(i, j)2 / (R(i, j)2+ G(i, j)2+ B(i, j)2)

Fig. 3(b)

1. Input: Input RGB image
2. Output: (Normalised) RGB image
3. Function: Translation of RGB value of each pixel according to the following formula. New R(i, j)= 255* R(i, j) / (R(i, j)+ G(i, j)+ B(i, j)) New G(i, j)= 255* G(i, j) / (R(i, j)+ G(i, j)+ B(i, j)) New B(i, j)= 255* B(i, j) / (R(i, j)+ G(i, j)+ B(i, j))

Fig. 3(c)

	Step	Input	Output	Parameter(unfixed)
(a)	3D Histogram	RGB image	3D histogram	Bucket size
(b)	Backprojection	RGB image 3D histogram 3D histogram(temp1) 3D histogram(temp2) 3D histogram(temp3) 3D histogram(tempn)	BPimage	Bucket size Number of templates Scale
(c)	Reduction of image size	BPimage	RBPimage	(Reduction rate = 1/2) Mx=My=2
(d)	Smoothing1	RBPimage	SRBPimage	Gauss filter size:9 (sigma=1)
(e)	Histogram	SRBPimage	histogram	(Xs, Ys)(Xe, Ye):(0, 0)(127, 127)
(f)	Threshold value search	histogram	TH	fTH Pm:255, Search Direction:Backword
(g)	Threshold of image	SRBPimage	BiBPimage	Const1:1, Const2:0, TH1:TH, TH2:255 (Xs, Ys)(Xe, Ye):(0, 0)(127, 127)
(h)	Binary Erosion (Repeat)	BiBPimage No. of erosion	ErBiBPimage	Const1:0, Const2:1, Mx:3, My:3 No. of erosion =SQR(fTH)/12.0
(i)	Binary Dilation* (Repeat)	ErBiBPimage BiBPimage No. of dilation	DiErBiBPimage	Const1:0, Const2:1, Mx:3, My:3 No. of dilation =No. of erosion* 1.6
(j)	Binary Dilation (Repeat)	DiErBiBPimage No. of dilation	D2ErBiBPimage	Const1:0, Const2:1, Mx:3, My:3 No. of dilation =SQR(fTH)/12.0
(k)	Binary Erosion (Repeat)	D2ErBiBPimage No. of erosion	D2E2BiBPimage	Const1:0, Const2:1, Mx:3, My:3 No. of erosion =SQR(fTH)/12.0
(l)	Projection X&Y	D2E2BiBPimage	projectionX projectionY	(Xs, Ys)(Xe, Ye):(0, 0)(127, 127)
(m)	Projection Search	projectionX projectionY	Location coordinate (Xsf, Ysf) (Xef, Yef)	Xmin:0, Xmax:127 Ymin:0, Ymax:127 N=0.1
(n)	Area counting	D2E2BiBPimage	Af: Area of face	(Xs, Ys)(Xe, Ye):(Xsf, Ysf) (Xef, Yef) Const1:1

22

Fig.4

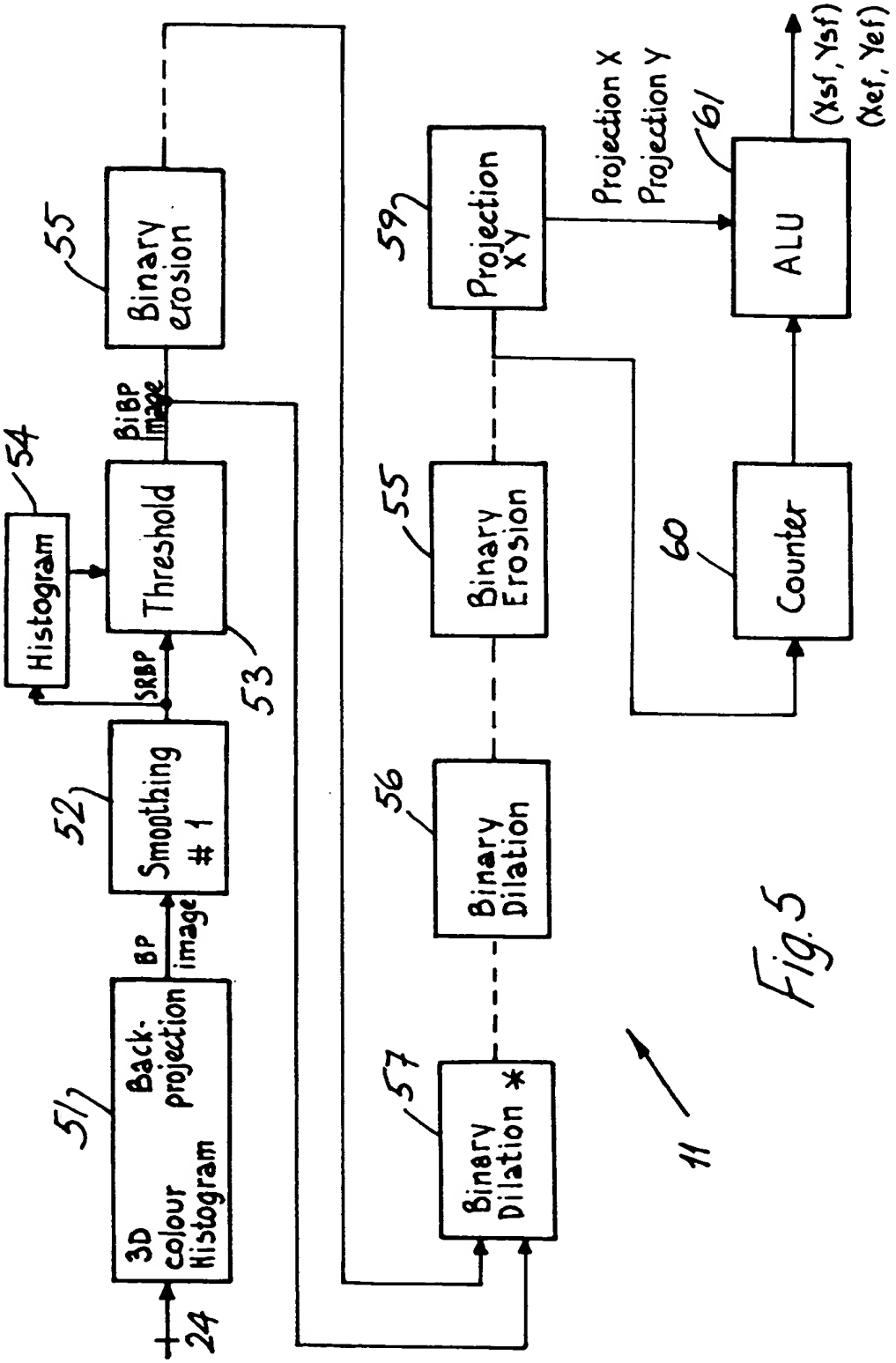

24
3D colour Histogram
51
Back-projection
BP image
52
Smoothing # 1
SRBP
Histogram
54
Threshold
BiBP image
53
Binary erosion
55
Binary Dilation *
57
Binary Dilation
56
Binary Erosion
55
Projection XY
59
Projection X
Projection Y
Counter
60
ALU
61
(Xsf, Ysf)
(Xef, Yef)
11

Fig. 5

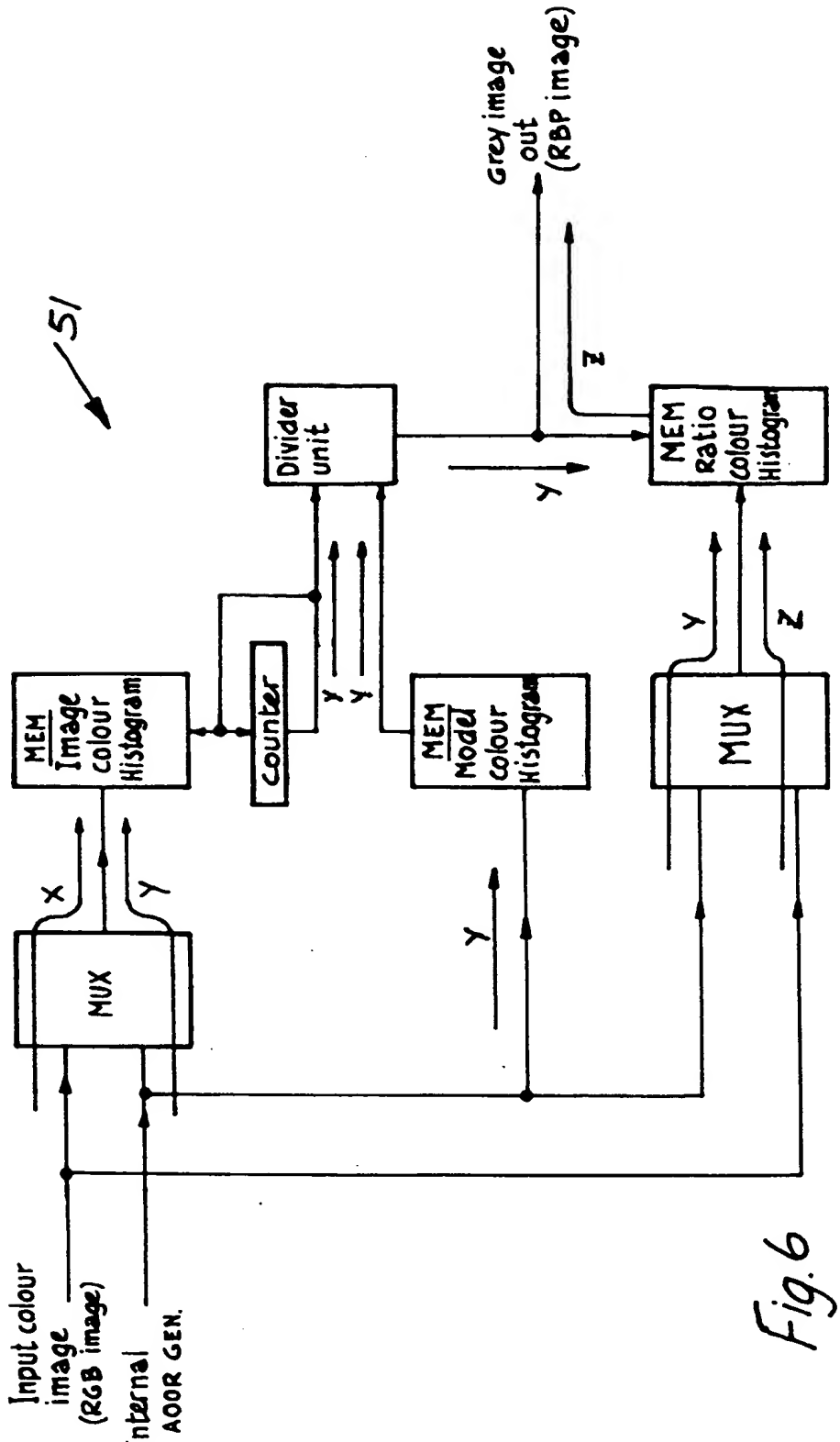

51
Grey image out (RBP image)
Divider unit
MEM Ratio colour Histogram
MEM Image colour Histogram
Counter
MEM Model colour Histogram
MUX
MUX
Input colour image (RGB image)
Internal ADDR GEN.
X
Y
Y
Y
Y
Y
Z
Z

Fig. 6

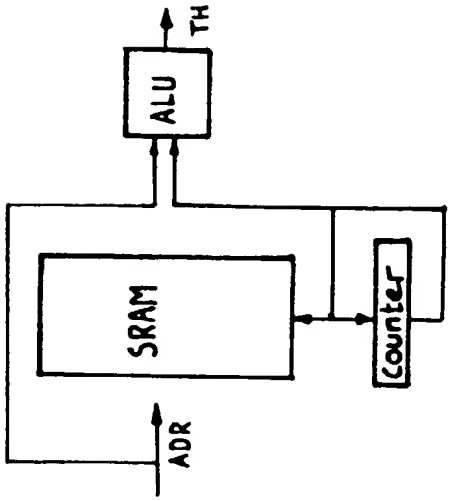


Fig. 7(b)

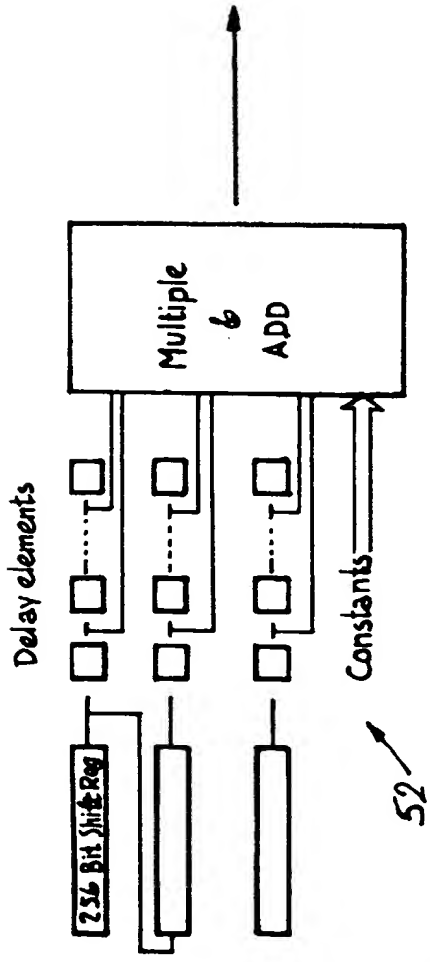


Fig. 7(a)

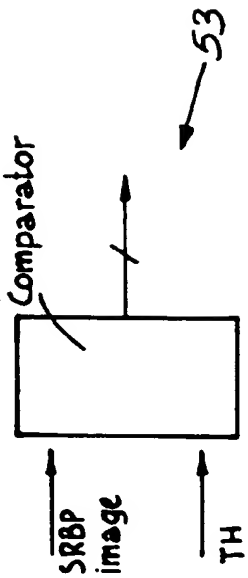


Fig. 7(c)

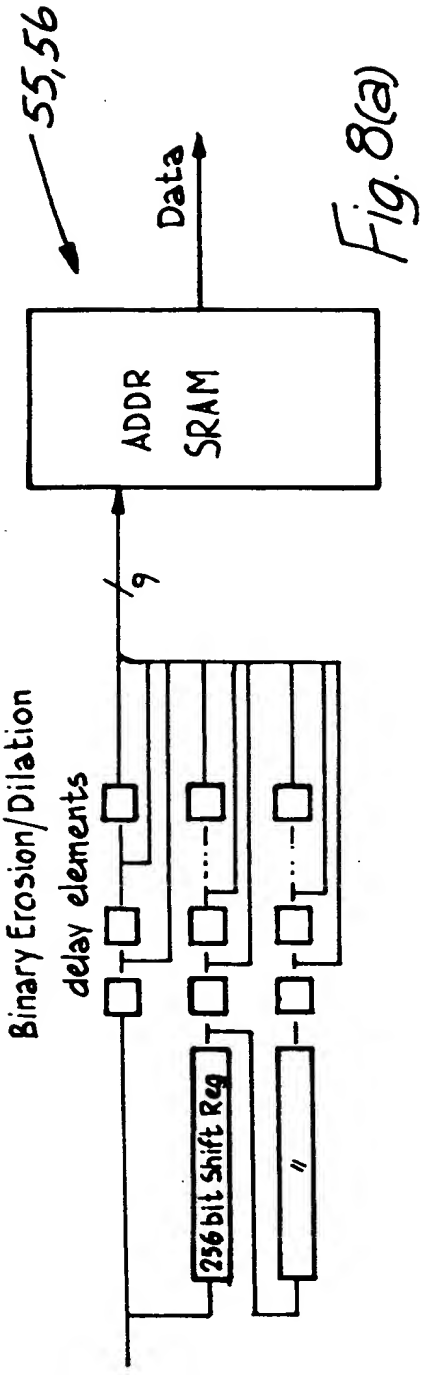

55,56
Data
ADDR
SRAM
9
Binary Erosion/Dilation
delay elements
256 bit Shift Reg
"

Fig. 8(a)

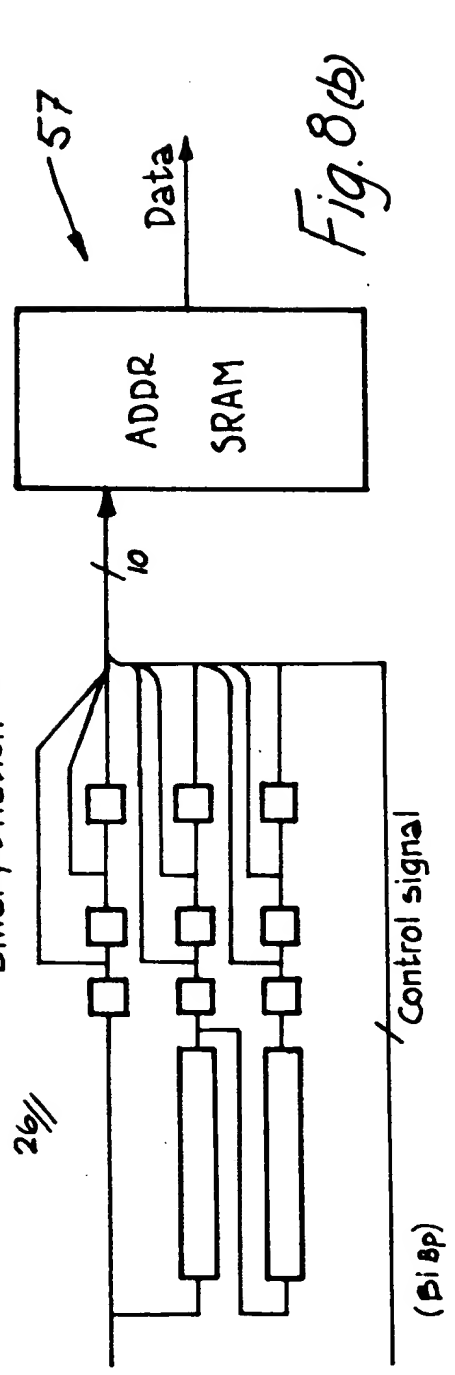

57
Data
ADDR
SRAM
10
Binary Dilation *
26
Control signal
(Bi Bp)

Fig. 8(b)

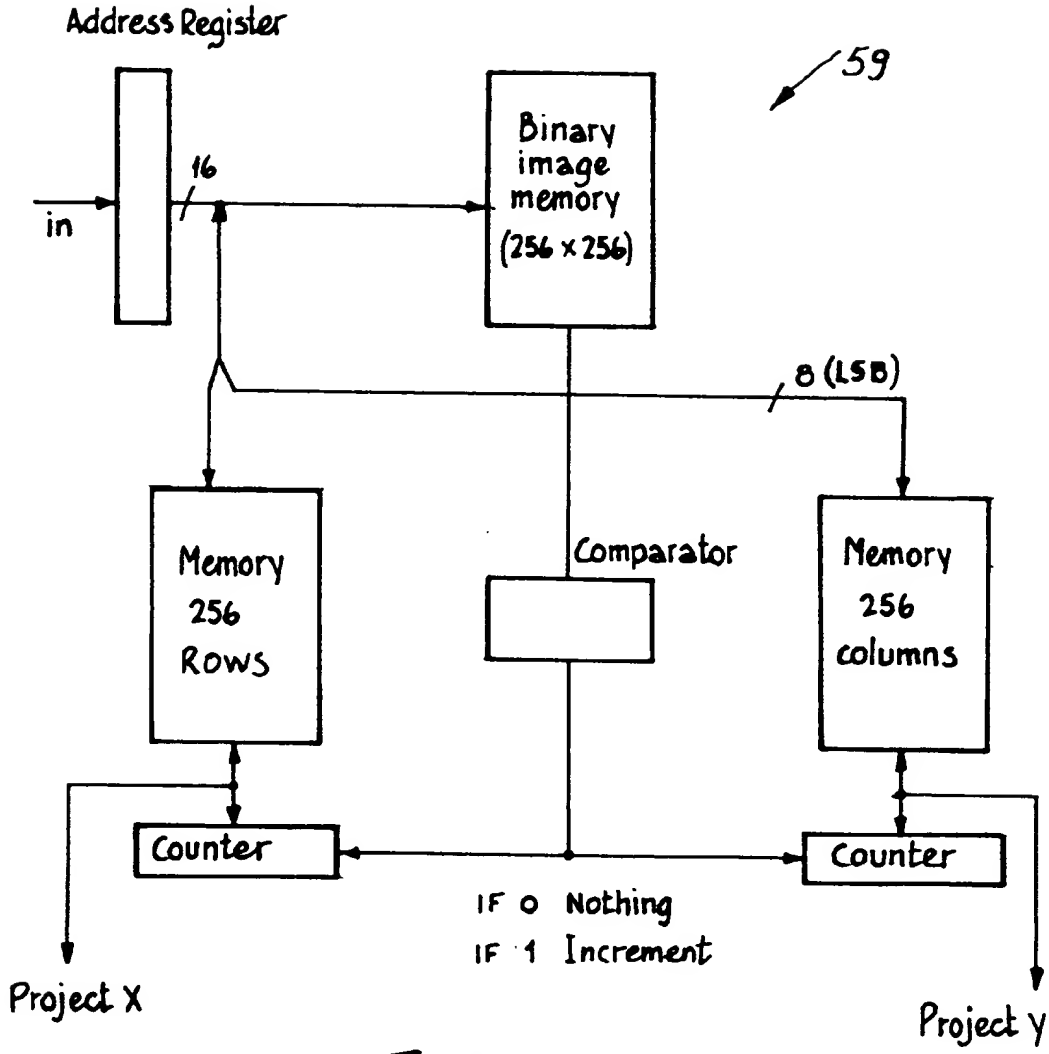

Address Register
59
Binary image memory (256 x 256)
16
in
8 (LSB)
Memory 256 Rows
Comparator
Memory 256 columns
Counter
Counter
IF 0 Nothing
IF 1 Increment
Project X
Project y

Fig. 9

3D Histogram

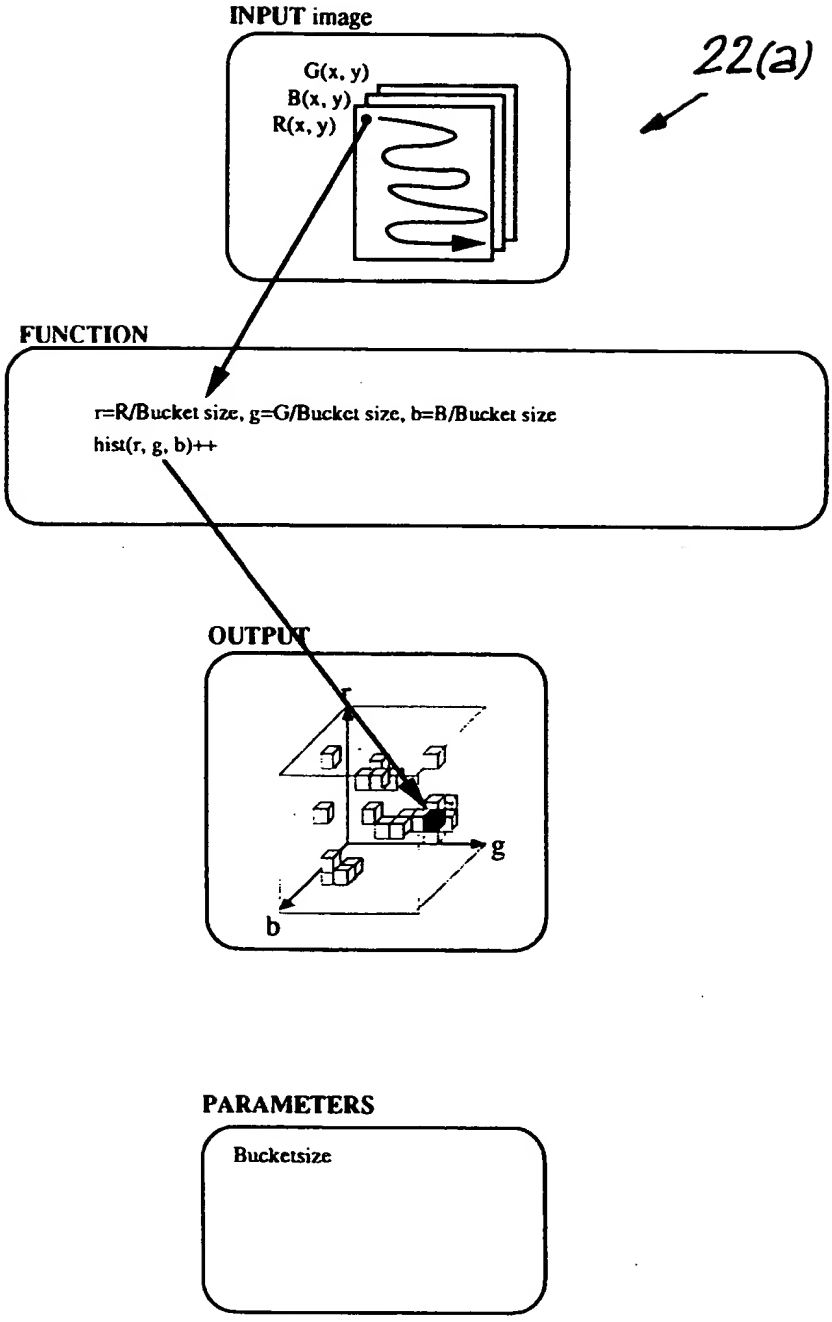


Fig. 10

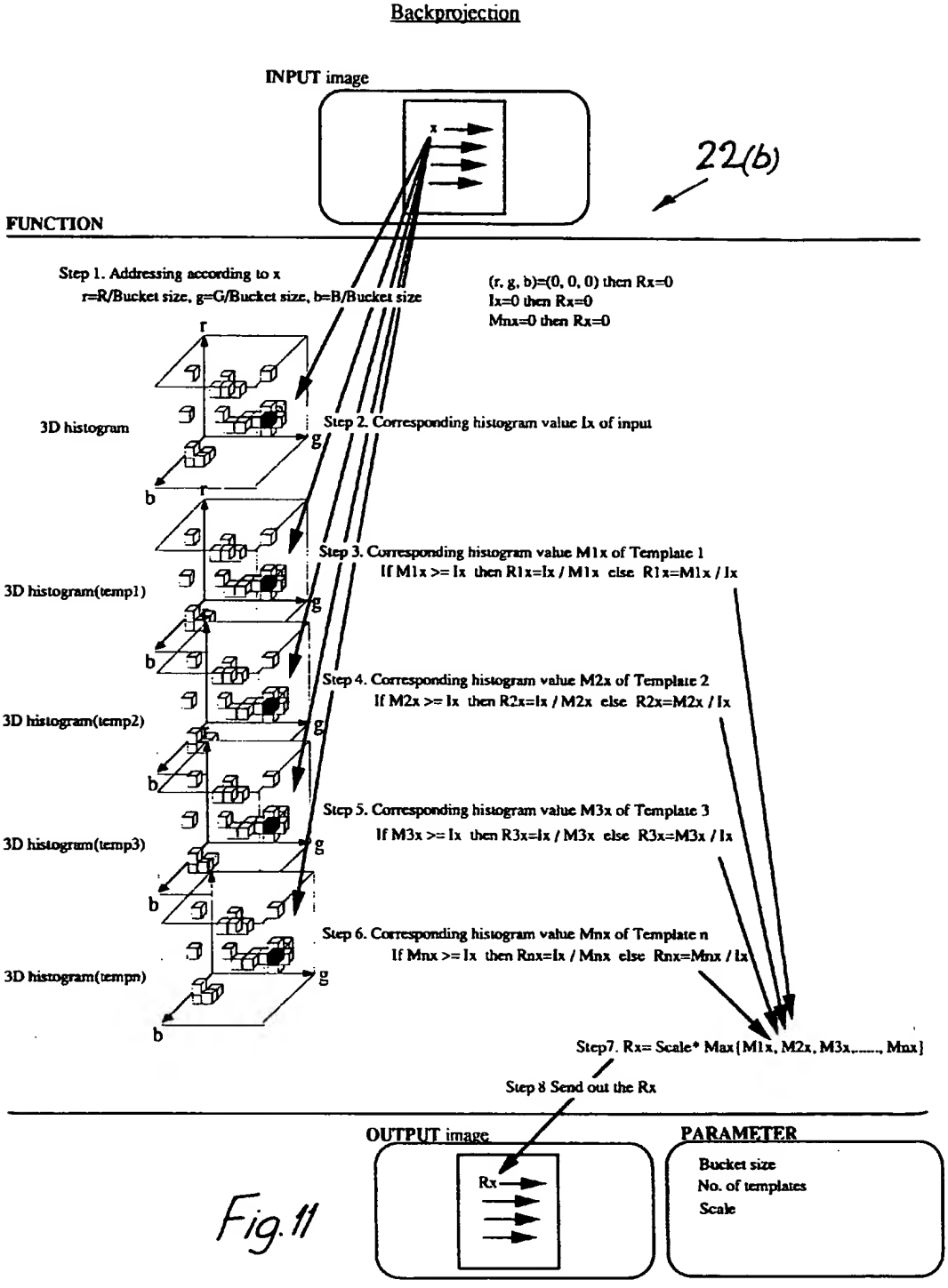
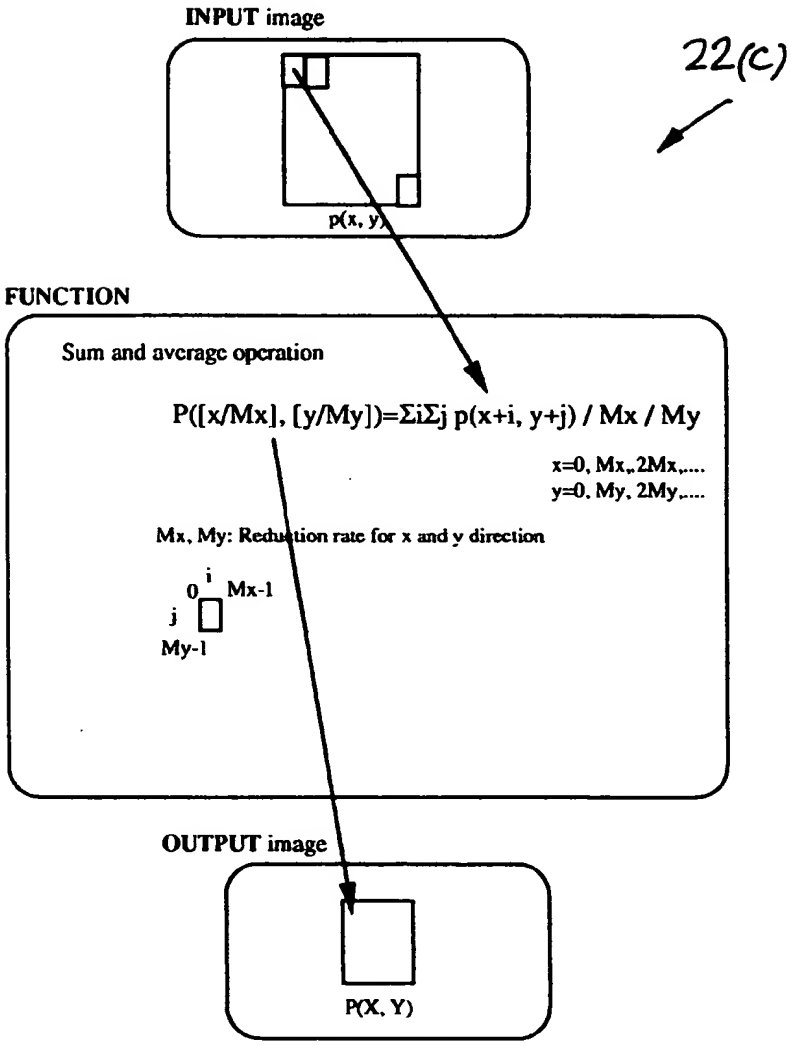

Backprojection
INPUT image
x
22(b)
FUNCTION
Step 1. Addressing according to x
r=R/Bucket size, g=G/Bucket size, b=B/Bucket size
(r, g, b)=(0, 0, 0) then Rx=0
Ix=0 then Rx=0
Mnx=0 then Rx=0
3D histogram
Step 2. Corresponding histogram value Ix of input
3D histogram(temp1)
Step 3. Corresponding histogram value M1x of Template 1
If M1x >= Ix then R1x=Ix / M1x else R1x=M1x / Ix
3D histogram(temp2)
Step 4. Corresponding histogram value M2x of Template 2
If M2x >= Ix then R2x=Ix / M2x else R2x=M2x / Ix
3D histogram(temp3)
Step 5. Corresponding histogram value M3x of Template 3
If M3x >= Ix then R3x=Ix / M3x else R3x=M3x / Ix
3D histogram(tempn)
Step 6. Corresponding histogram value Mnx of Template n
If Mnx >= Ix then Rnx=Ix / Mnx else Rnx=Mnx / Ix
Step7. Rx= Scale* Max{M1x, M2x, M3x,....., Mnx}
Step 8 Send out the Rx
OUTPUT image
Rx
PARAMETER
Bucket size
No. of templates
Scale

Fig. 11

Reduction of image size



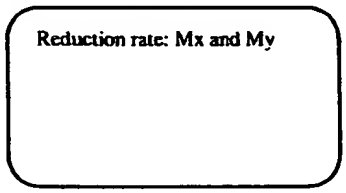


Fig.12

Convolution (Smoothing # 1

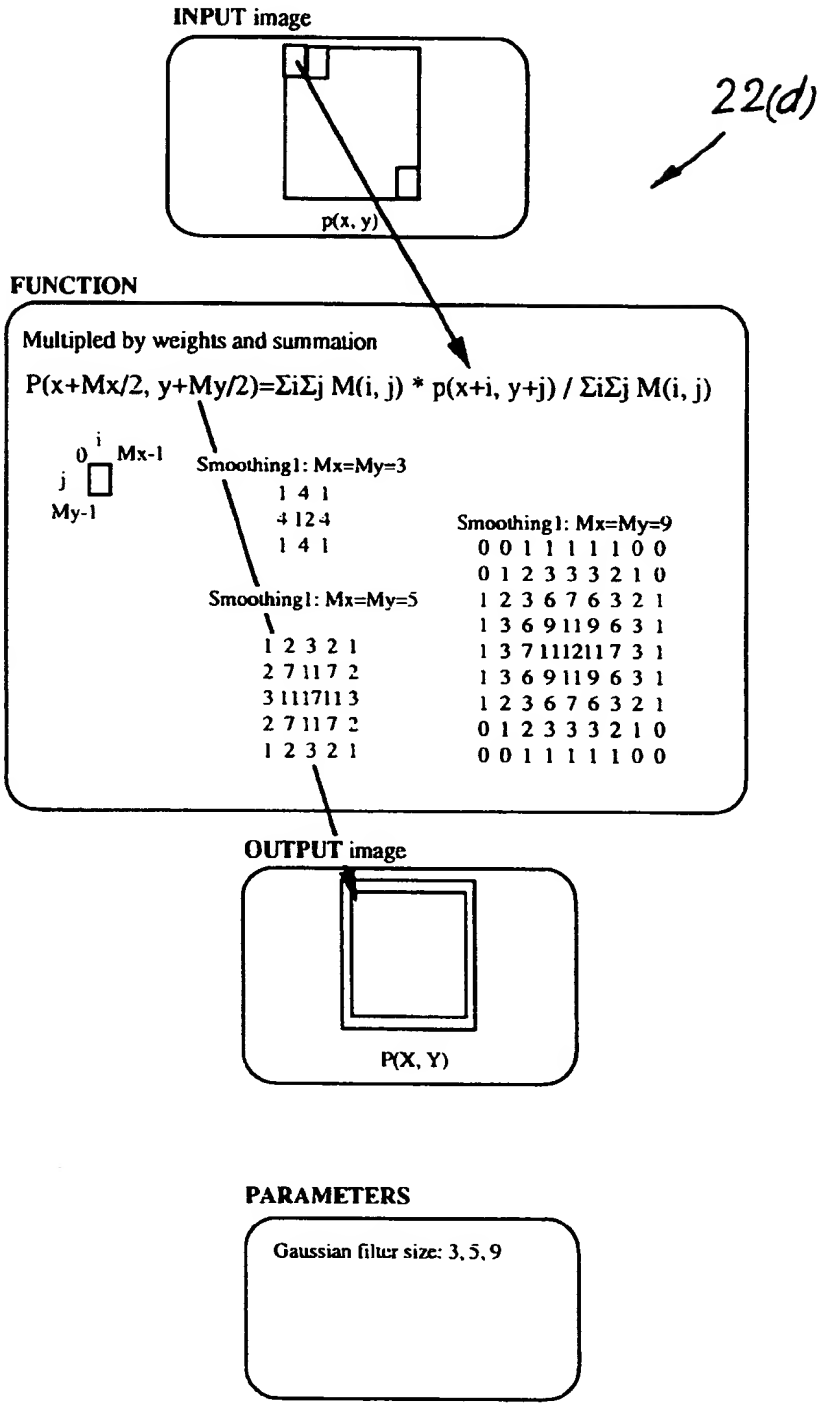


Fig. 13

Histogram

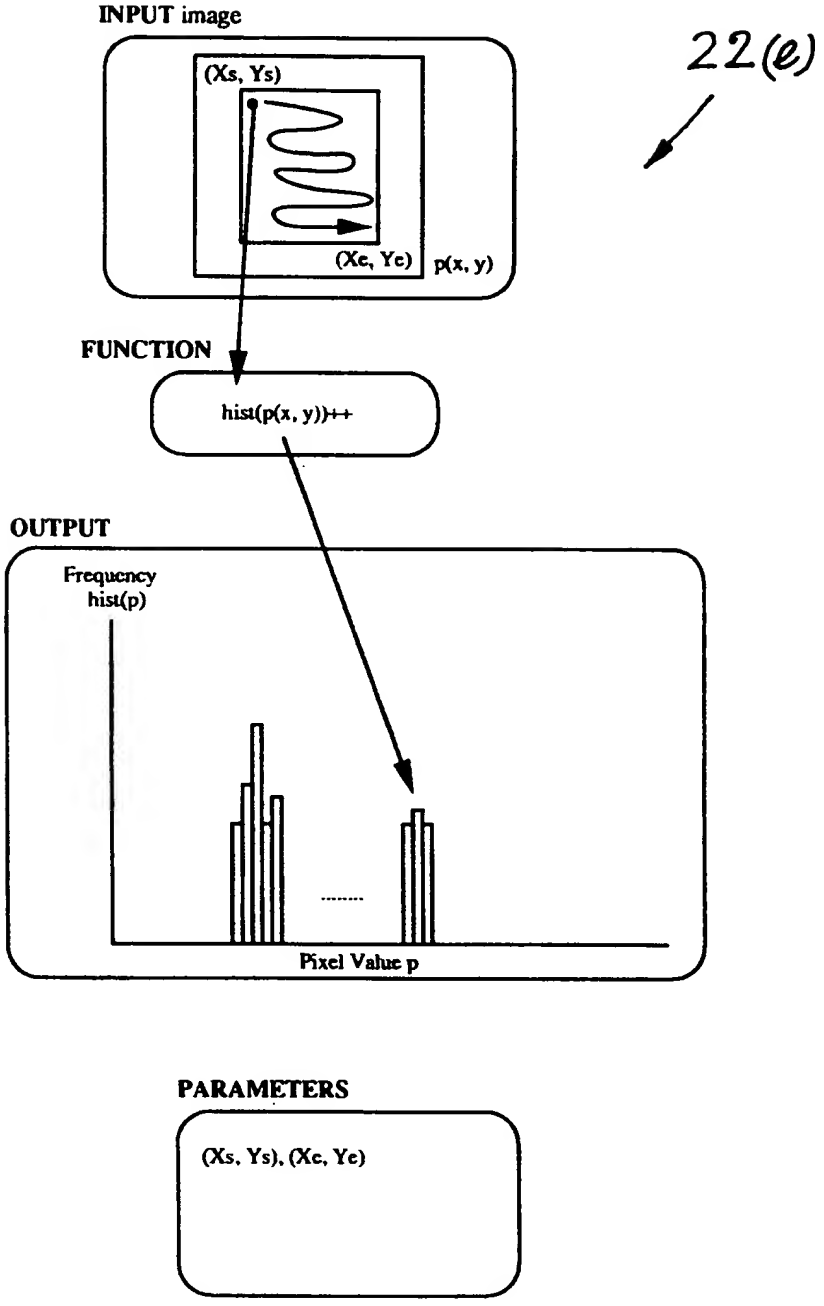


Fig. 14

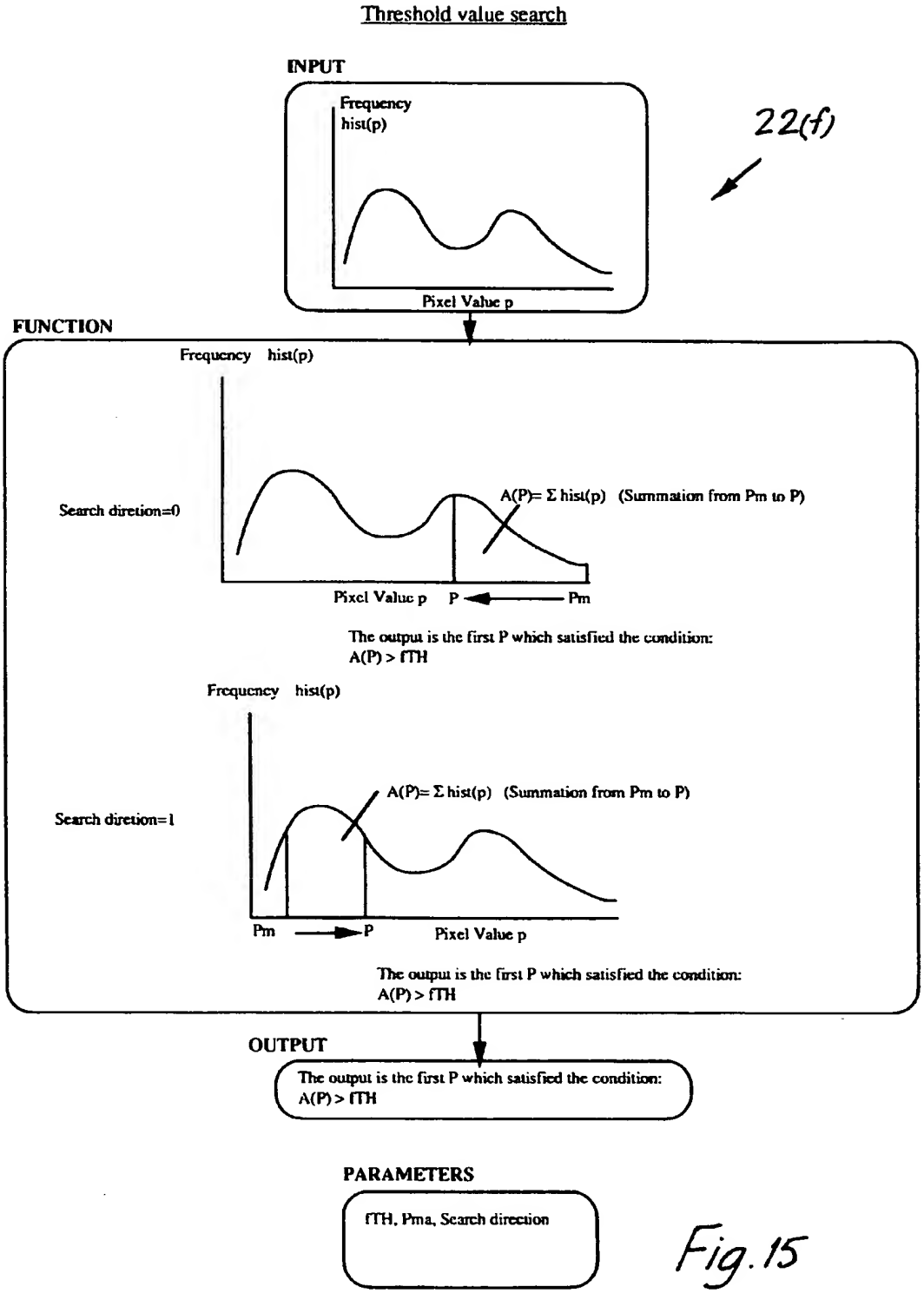

Threshold value search
INPUT
Frequency
hist(p)
Pixel Value p
22(f)
FUNCTION
Frequency hist(p)
Search direction=0
A(P)= Σ hist(p) (Summation from Pm to P)
Pixel Value p
P
Pm
The output is the first P which satisfied the condition:
A(P) > fTH
Frequency hist(p)
Search direction=1
A(P)= Σ hist(p) (Summation from Pm to P)
Pm
P
Pixel Value p
The output is the first P which satisfied the condition:
A(P) > fTH
OUTPUT
The output is the first P which satisfied the condition:
A(P) > fTH
PARAMETERS
fTH, Pma, Search direction

Fig. 15

Threshold of image

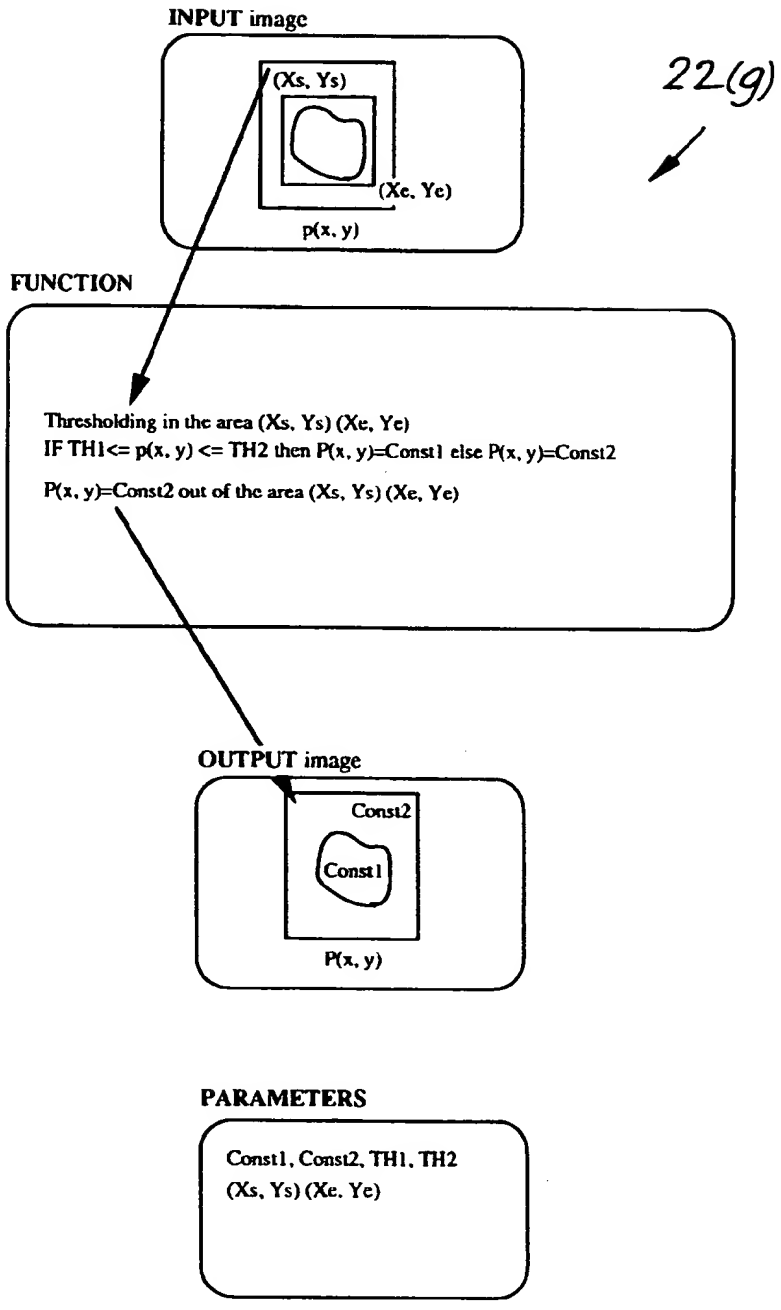


Fig.16

Binary Erosion

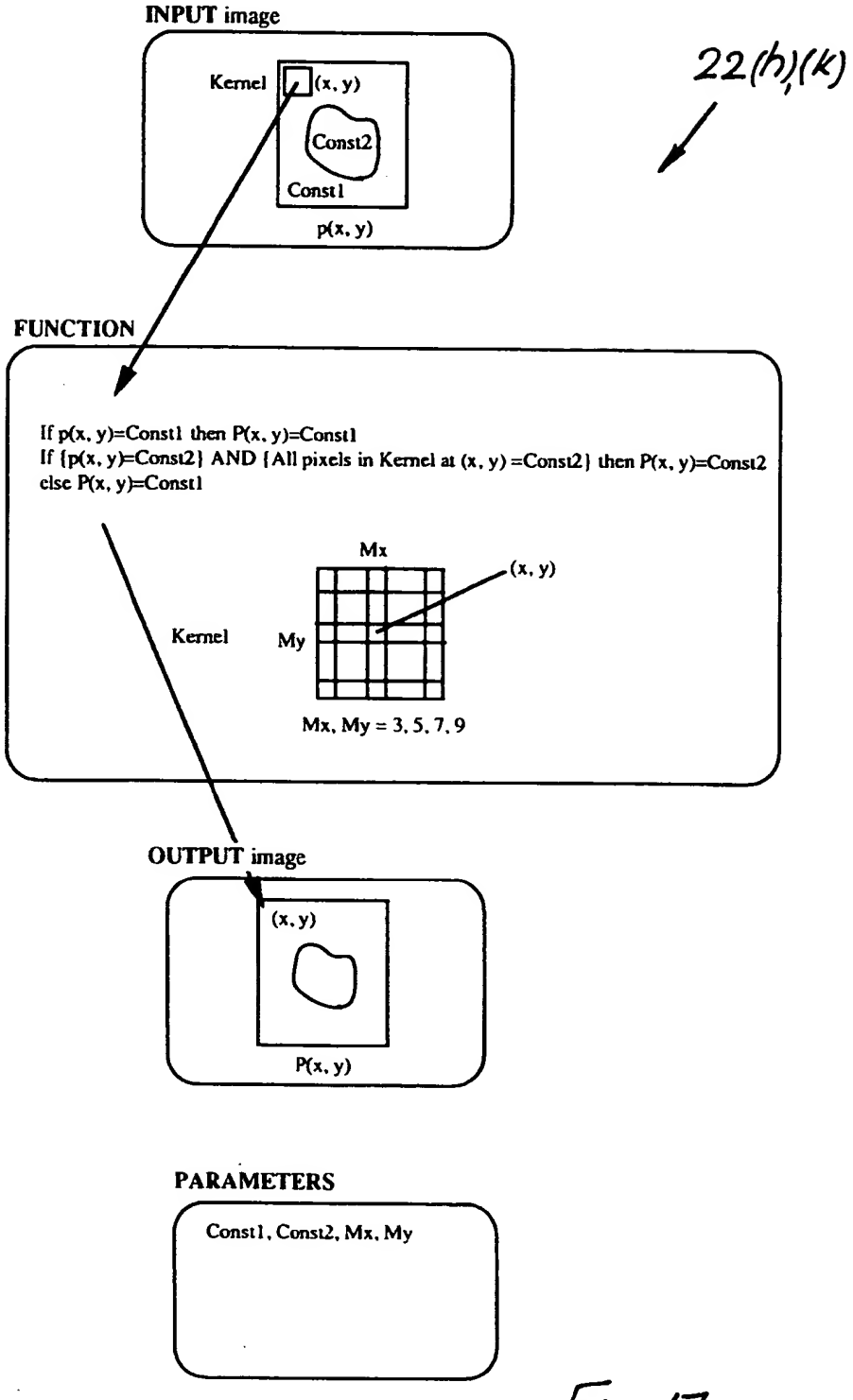


Fig. 17

Binary Dilation*

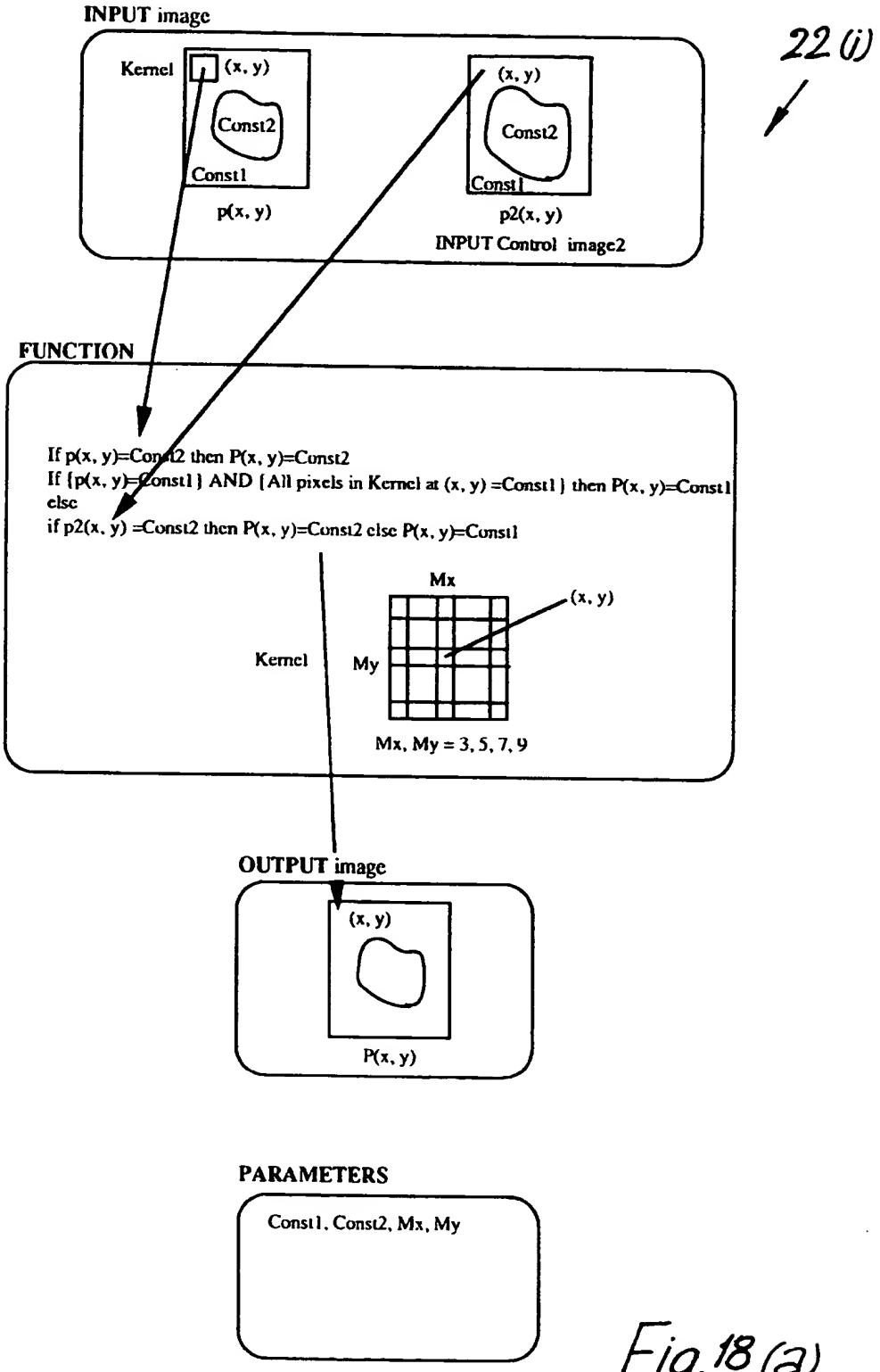


Fig. 18 (a)

Binary Dilation

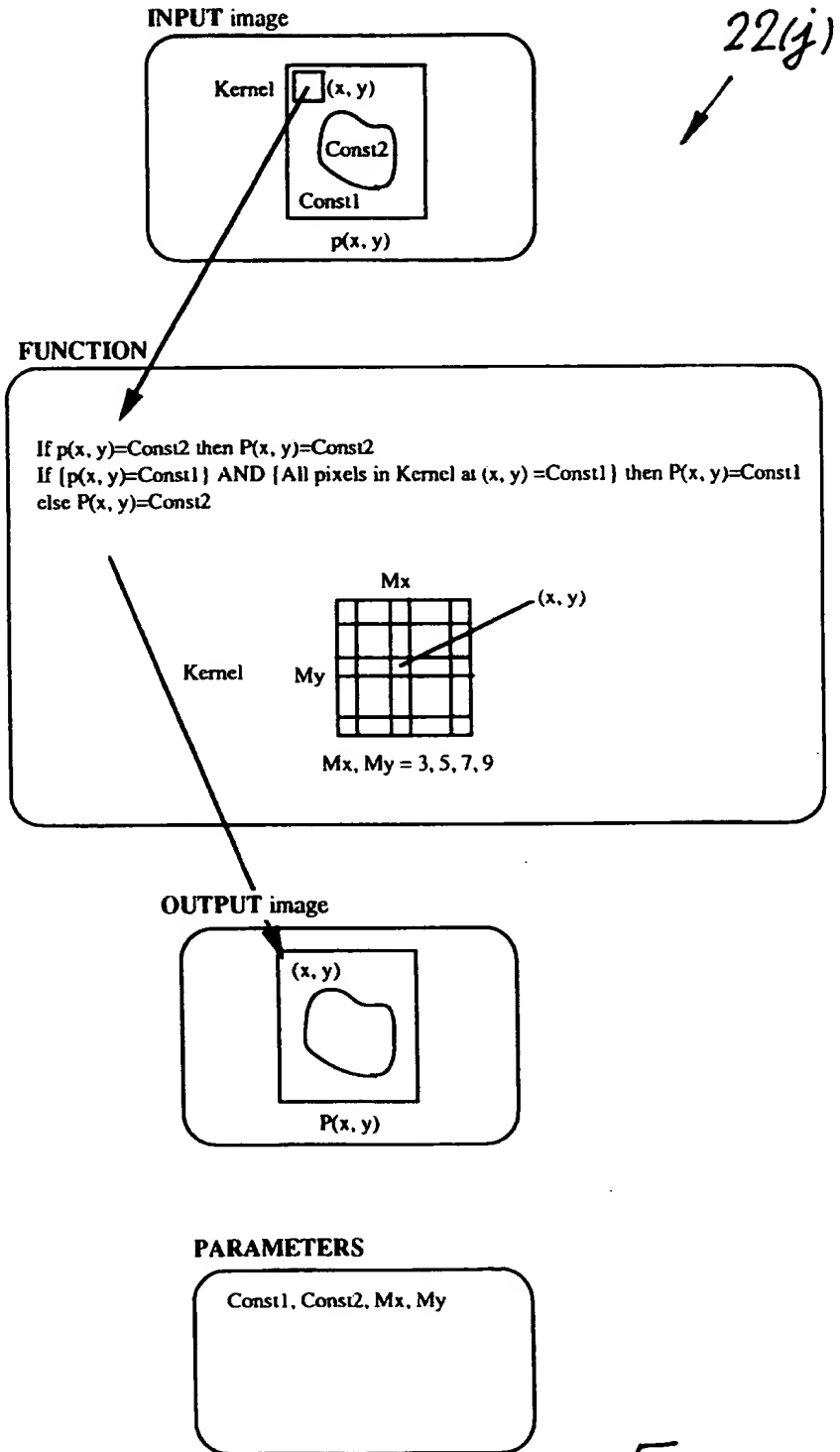


Fig. 18(b)

Projection X&Y

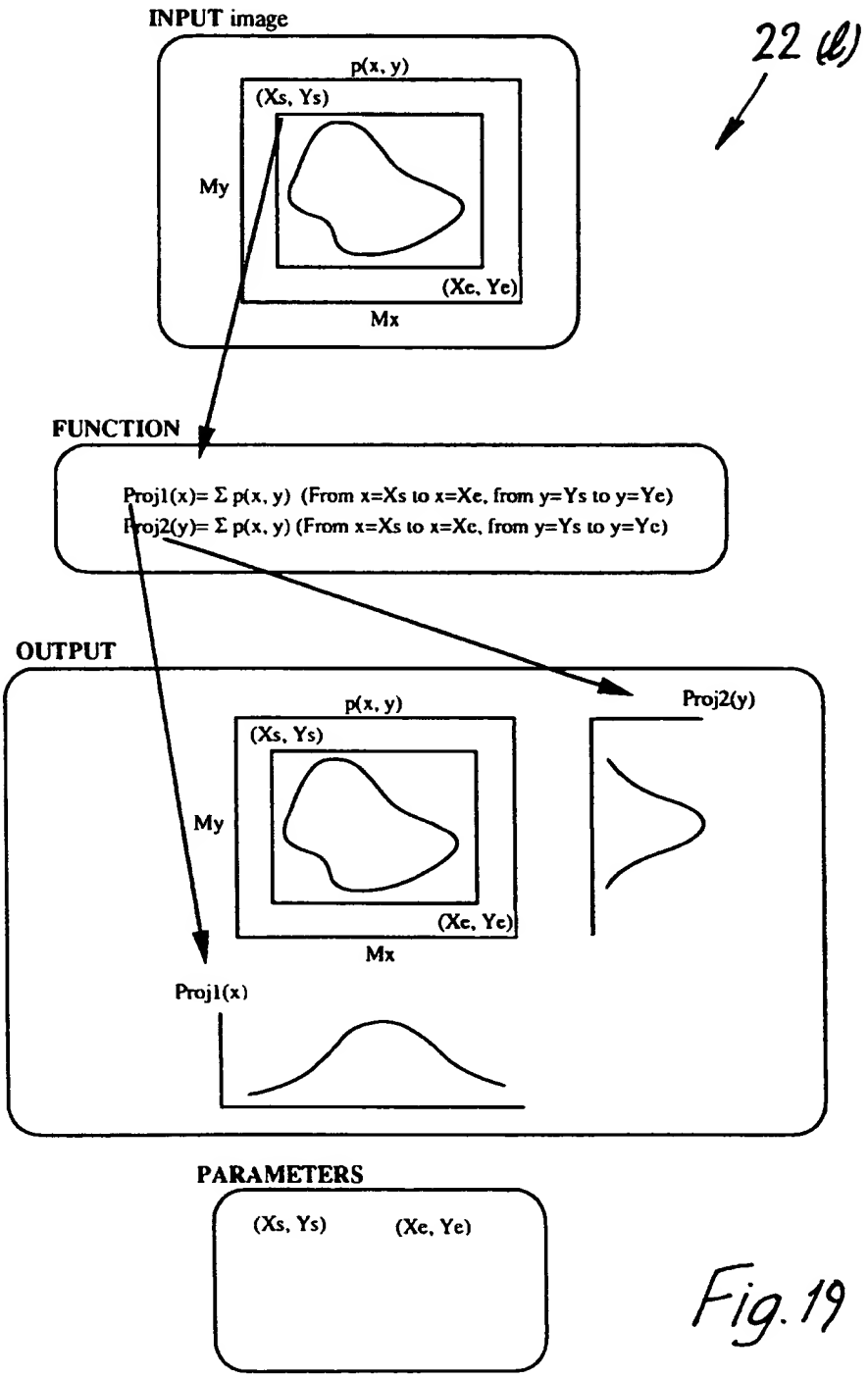
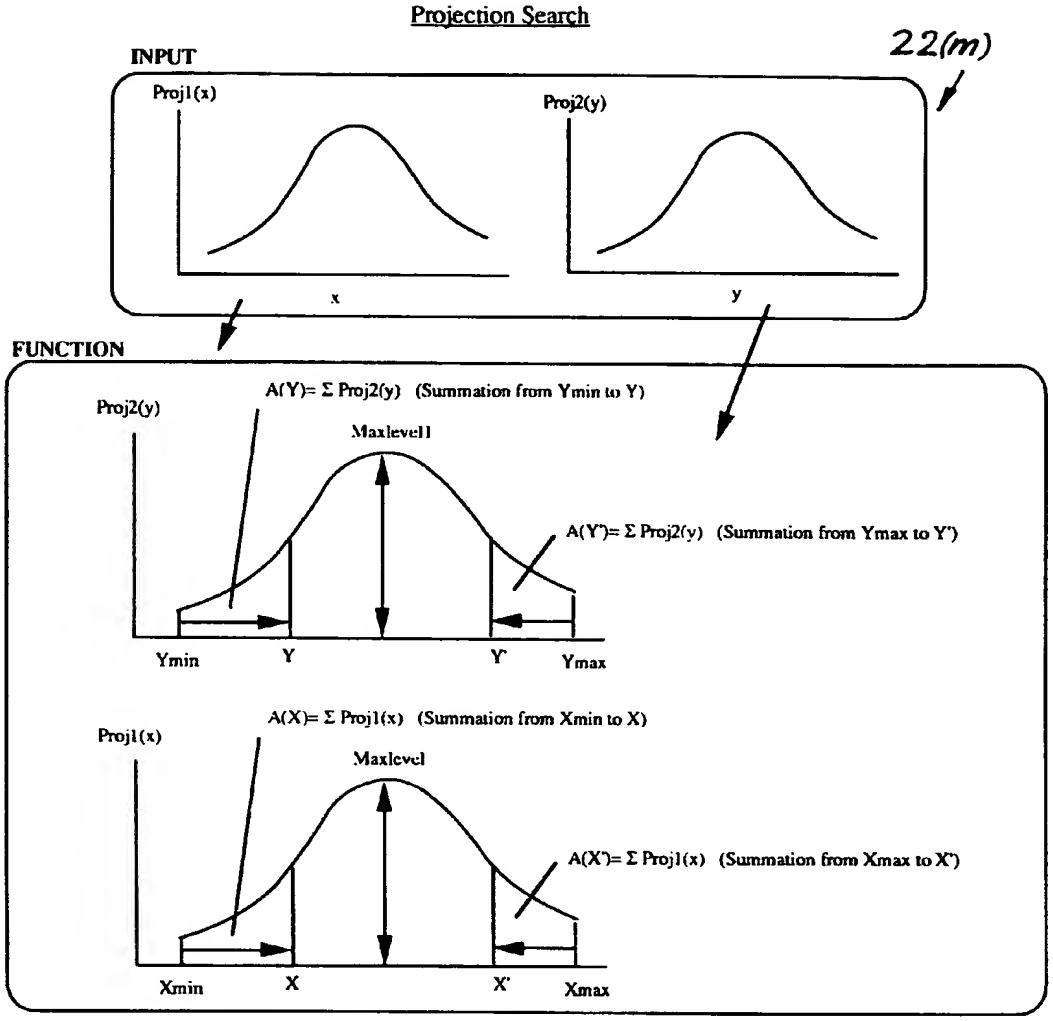


Fig. 19



OUTPUT

The output Xs is the first X which satisfied the condition: A(X) > Maxlevel* N
The output Xe is the first X' which satisfied the condition: A(X') > Maxlevel* N

The output Ys is the first Y which satisfied the condition: A(Y) > Maxlevel1* N
The output Ye is the first Y' which satisfied the condition: A(Y') > Maxlevel1* N

PARAMETERS

Xmin, Xmax
Tmin, Ymax
N

Fig. 20

Area counting

22(n)

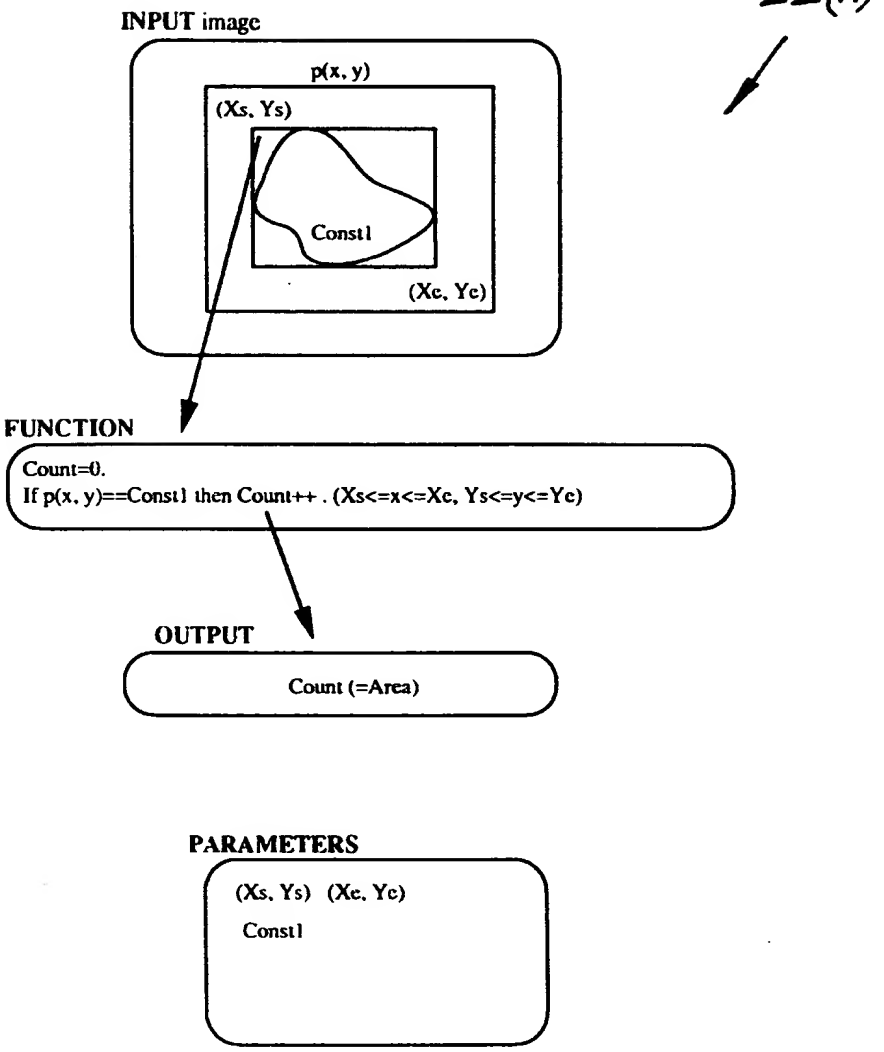


Fig. 21

Coloured fingertip detection

	Step	Input	Output	Parameter (unfixed)
(a)	3D Histogram	RGB image	3D histogram	Bucket size
(b)	Backprojection	RGB image 3D histogram 3D histogram(temp1) 3D histogram(temp2) 3D histogram(temp3) 3D histogram(tempn)	BPimage	Bucket size Number of templates Scale
(c)	Smoothing2	BPimage	Smoothed BPimage	Filter size: 5 (= avarage size)
(d)	Max value search	Smoothed BPimage	Max-value XY coordinate	(Xs, Ys)(Xe, Ye): (0, 0)(255, 255)
(e)	Smoothing1	Smoothed BPimage	SBPimage	Gauss filter size:5 (sigma=1)
(f)	Histogram	SBPimage	BPhistogram	(Xs, Ys)(Xe, Ye)<-- XY coordinate, width & height
(g)	Threshold value search	BPhistogram	TH	fTH Pm:255, Search Direction:Backword
(h)	Threshold of image	SBPimage	BiBPimage	Const1:1, Const2:0, TH1:TH, TH2:255 (Xs, Ys)(Xe, Ye)<-- XY coordinate, width & height
(i)	Binary Erosion (Repeat)	BiBPimage	ErBiBPimage	Const1:0, Const2:1, Mx:3, My:3 No. of erosion =SQR(fTH)/12.0
(j)	Binary Dilation* (Repeat)	ErBiBPimage BiBPimage	DiErBiBPimage	Const1:0, Const2:1, Mx:3, My:3 No. of dilation =No. of erosion* 1.6
(k)	Projection X&Y	DiErBiBPimage	projectionX projectionY	(Xs, Ys)(Xe, Ye)<-- XY coordinate, width & height
(l)	Projection Search	projectionX projectionY	Location coordinate (Xst, Yst) (Xet, Yet)	Xmin, Xmax, Ymin, Ymax<-- XY coordinate, width & height N=0.1
(m)	Area counting	DiErBiBPimage	At: Area of face	(Xs, Ys)(Xe, Ye):(Xst, Yst) (Xet, Yet) Const1:1

25

Fig. 22

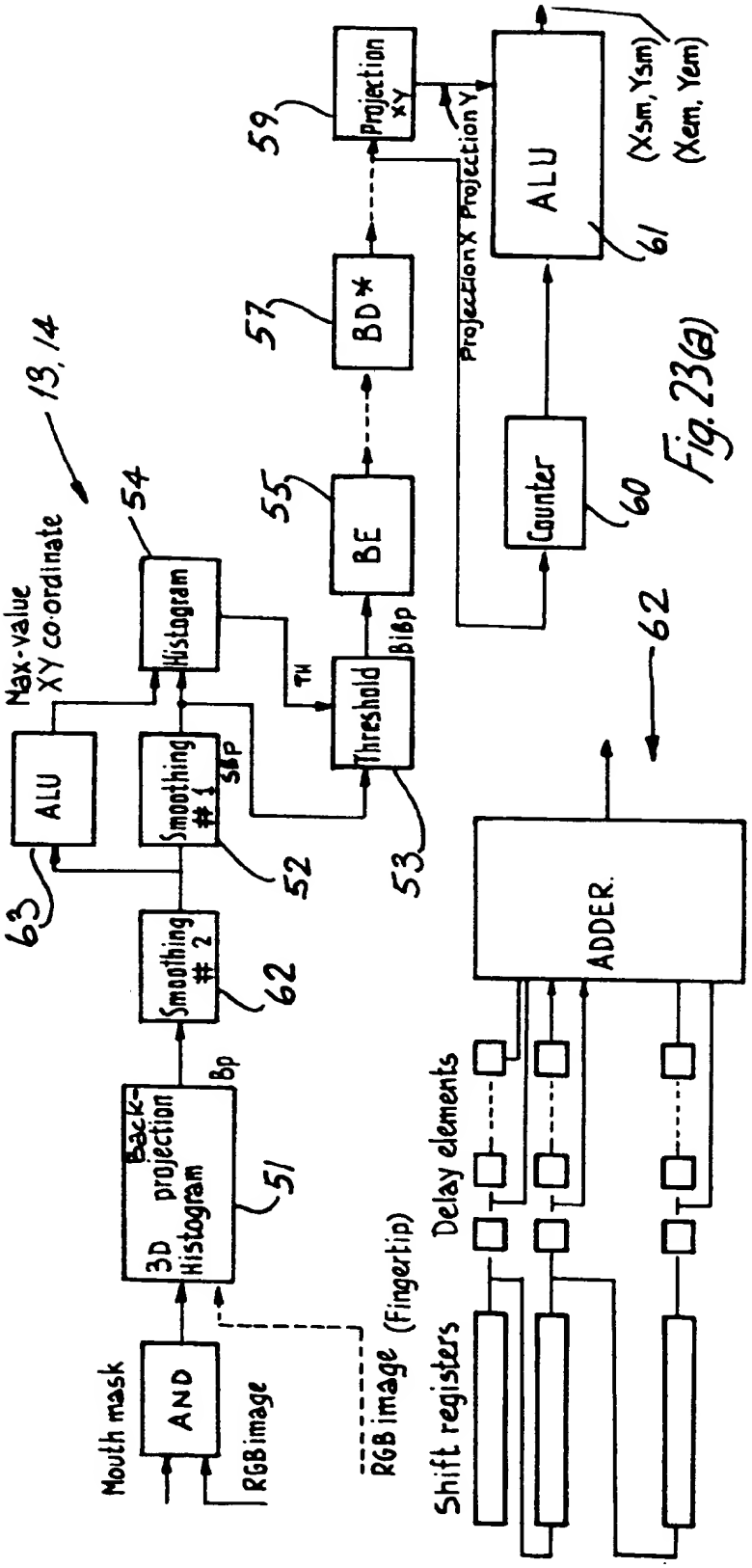


Fig. 23(a)

Fig. 23(b)

Convolution (Smoothing #2

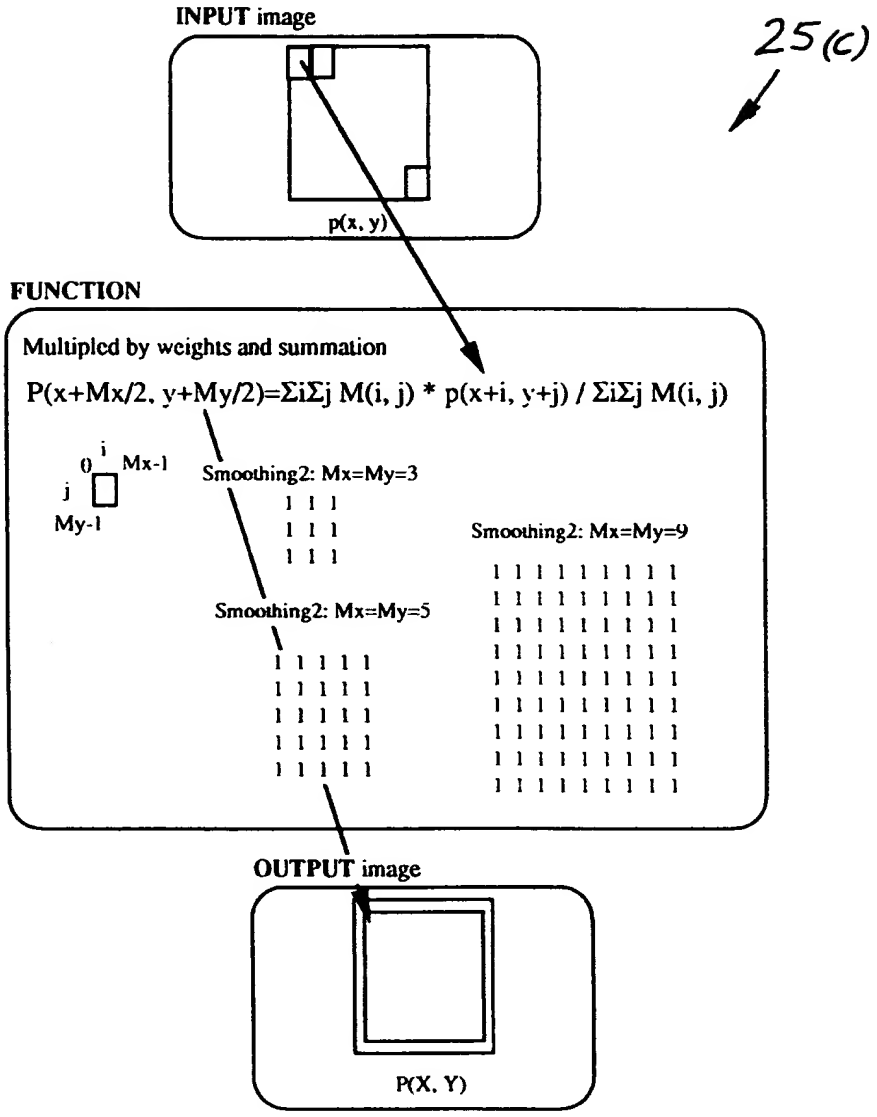
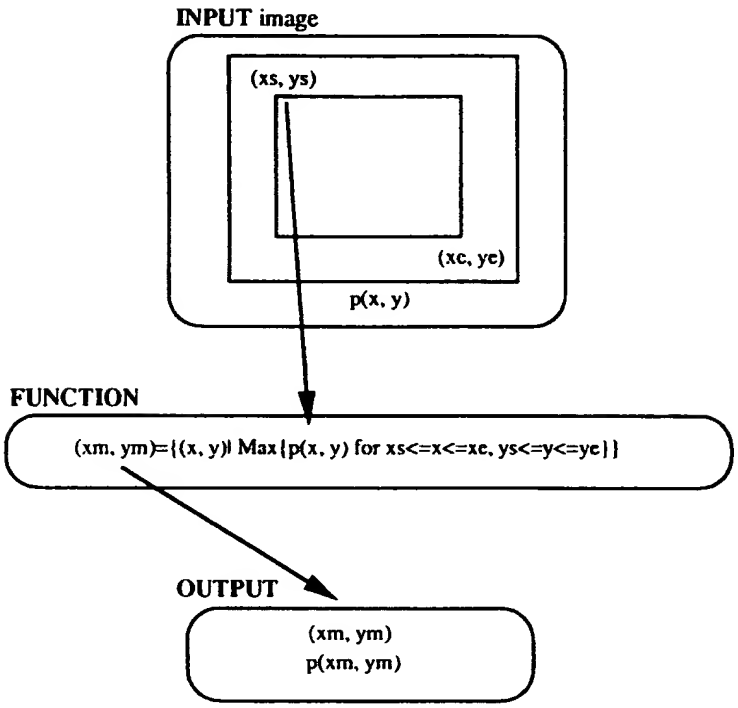


Fig. 24

Max value search

25(d)



PARAMETERS

(Xs, Ys) (Xe, Ye)

Fig. 25

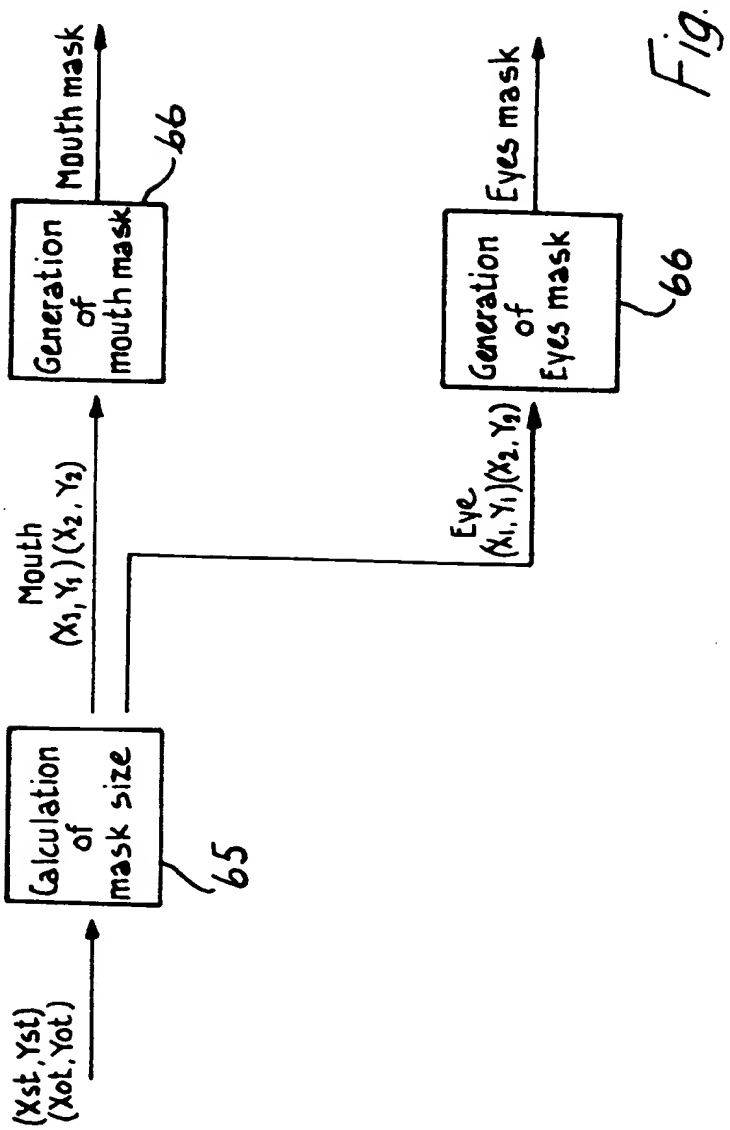

12
(Xst, Yst)
(Xot, Yot)
Calculation of mask size
65
Mouth (X1, Y1)(X2, Y2)
Eye (X1, Y1)(X2, Y2)
Generation of mouth mask
66
Mouth mask
Generation of Eyes mask
66
Eyes mask

Fig. 26

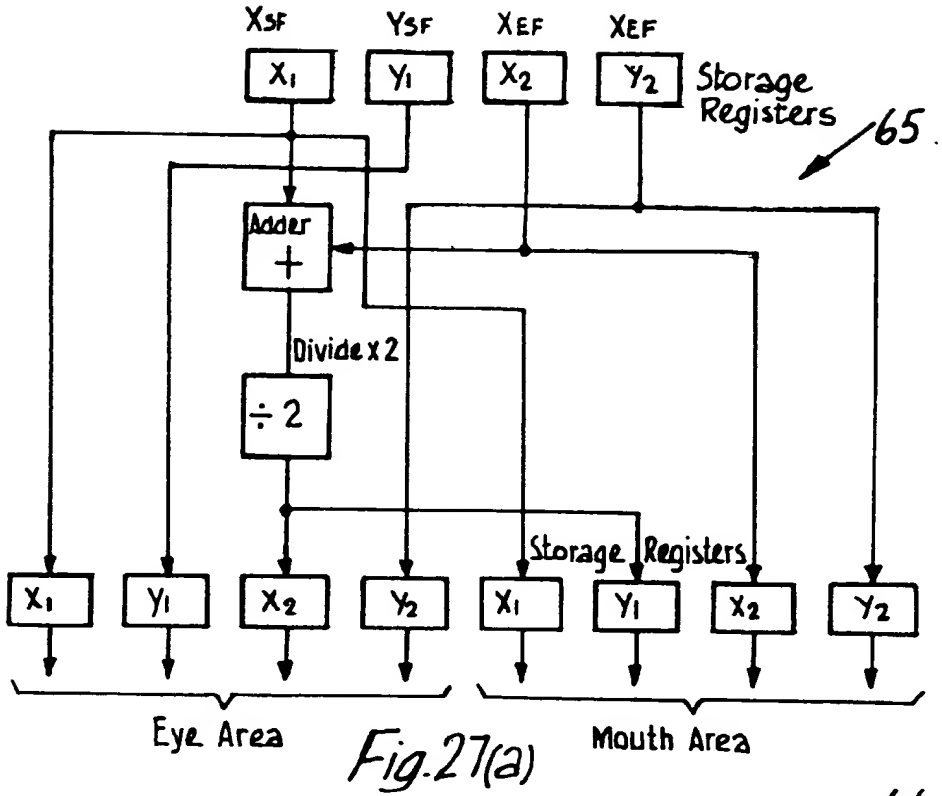


Fig.27(a)

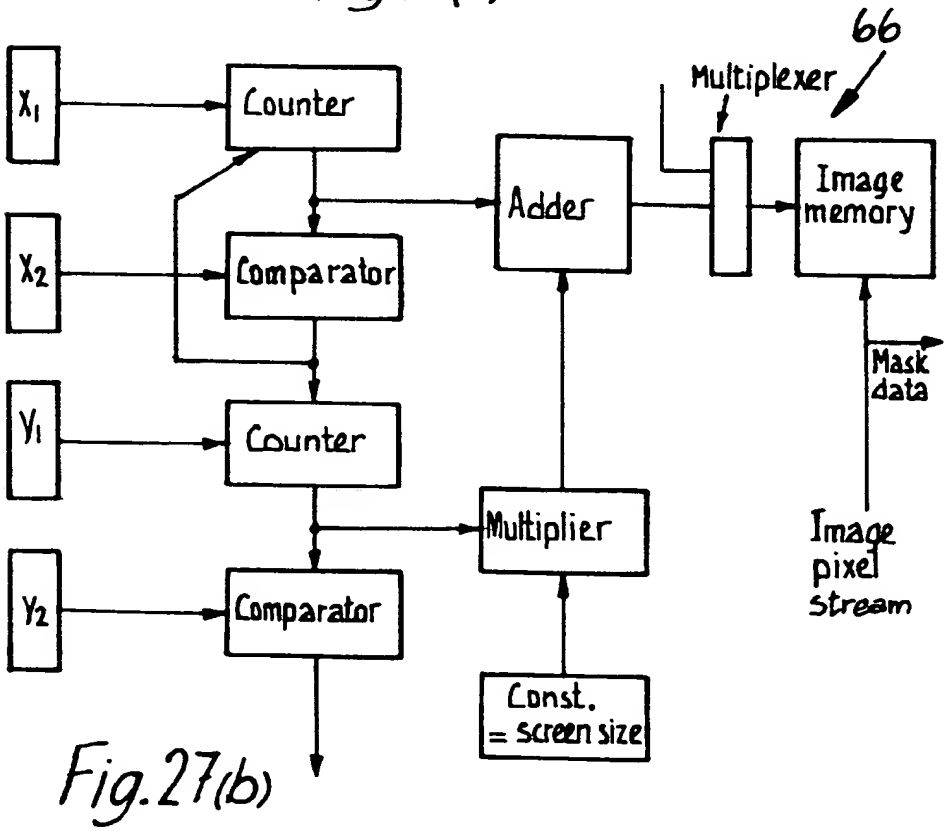


Fig.27(b)

Detection of facial part mask

30

	Step	Input	Output
(a)	Gene. of Position Mask of Mouth	Position: (Xsf, Ysf) (Xef, Yef)	MMaskimage : (Xsmm, Ysmm) (Xemm, Yemm)
(b)	Gene. of Position Mask of Eyes	Position: (Xsf, Ysf) (Xef, Yef)	EMaskimage : (Xsme, Ysme) (Xeme, Yeme)
(c)	Gene. of MouthMask (AND Operation)	BFimage MMaskimage : (Xsmm, Ysmm) (Xemm, Yemm)	MouthMask
(d)	Gene. of EyeMask (AND Operation)	BFimage EMaskimage : (Xsme, Ysme) (Xeme, Yeme)	EyesMask

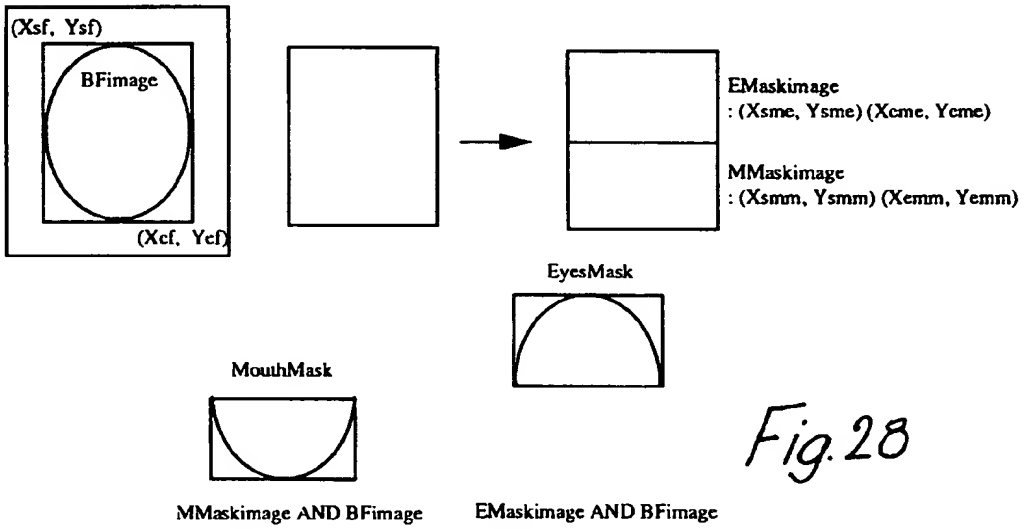


Fig. 28

31

Masking of the input image

Step	Input	Output
Mask the input image (AND Operation to bit plains)	(Norm) RGB image MouthMask	MRGB image

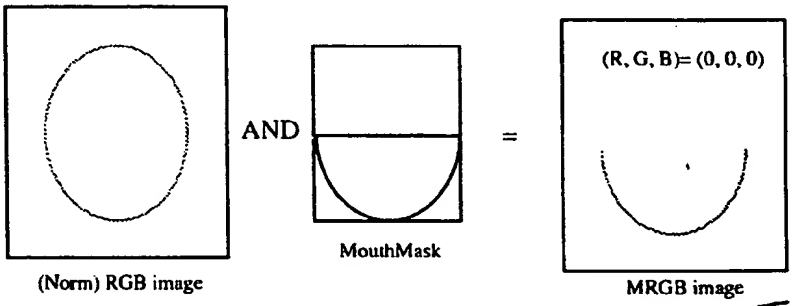


Fig. 29

Mouth area detection

	Step	Input	Output	Parameter (unfixed)
(a)	Histogram	MRGB image	3D histogram	Bucket size
(b)	Backprojection	MRGB image 3D histogram 3D histogram(temp1) 3D histogram(temp2) 3D histogram(temp3) 3D histogram(tempn)	BPimage	Bucket size Number of templates Scale
(c)	Smoothing2	BPimage	Smoothed BPimage	Filter size: 9 (= avarage size)
(d)	Max value search	Smoothed BPimage	Max-value XY coordinate	(Xs, Ys)(Xe, Ye): (0, 0)(255, 255)
(e)	Smoothing1	Smoothed BPimage	SBPimage	Gauss filter size (sigma=1)
(f)	Histogram	SBPimage	BPhistogram	(Xs, Ys)(Xe, Ye)<-- XY coordinate, width & height
(g)	Threshold value search	BPhistogram	TH	fTH Pm:255, Search Direction:Backword
(h)	Threshold of image	SBPimage	(Partial) BiBPimage	Const1:1, Const2:0, TH1:TH, TH2:255 (Xs, Ys)(Xe, Ye)<-- XY coordinate, width & height
(i)	Binary Erosion (Report)	BiBPimage	ErBiBPimage	Const1:0, Const2:1, Mx:3, My:3 No. of erosion =SQR(fTH)/12.0
(j)	Binary Dilation* (Report)	ErBiBPimage BiBPimage	DiErBiBPimage	Const1:0, Const2:1, Mx:3, My:3 No. of dilation =No. of erosion* 1.6
(k)	Projection X&Y	DiErBiBPimage	projectionX projectionY	(Xs, Ys)(Xe, Ye)<-- XY coordinate, width & height
(l)	Projection Search	projectionX projectionY	Location coordinate (Xsm, Xsm) (Xem, Yem)	Xmin, Xmax, Ymin, Ymax<-- XY coordinate, width & height N=0.1
(m)	Area counting	DiErBiBPimage	Am: Area of face	(Xs, Ys)(Xe, Ye):(Xsm, Ysm) (Xem, Yem) Const1:1

32

Fig.30

Eye area detection

	Step	Input	Output	Parameter (unfixed)
(a)	Transformation to grey scale	ERGB image	GERGB image	
(b)	Reduction of image size	GERGB image	RGERGB image	Mx=My=2 (Reduction rate = 1/2)
(c)	Multi -Template Matching	RGERGB image Eye Template1 Eye Template2 Eye Template3 Eye Templaten	Position: (Xe1, Ye1) Position: (Xe2, Ye2)	

33

Fig. 31(a)

Multi- Template Matching

Step	Input	Output	Parameter (unfixed)
Template Matching	RGERGB image Eye Template1	TM1 image	Template address N
Template Matching	RGERGB image Eye Template2	TM2 image	Template address N
Template Matching	RGERGB image Eye Template3	TM3 image	Template address N
Template Matching	RGERGB image Eye Template n	TMn image	Template address N
Max pixel selection	TM1 image TM2 image TM3 image TMn image	TM image	No. of image its address
Convolution (Smoothing2)	TM image	CTM image	Filter size: 9
Max value search	CTM image	Position: (Xe1, Ye1)	(Xs, Ys)(Xe, Ye):(0, 0)(127, 127)
Set Constant	CTM image	CTM0 image	(Xs, Ys)(Xe, Ye)<--(Xe1, Ye1) Const1
Max value search	CTM0 image	Position: (Xe2, Ye2)	(Xs, Ys)(Xe, Ye):(0, 0)(127, 127)

33(c)

Fig. 31(b)

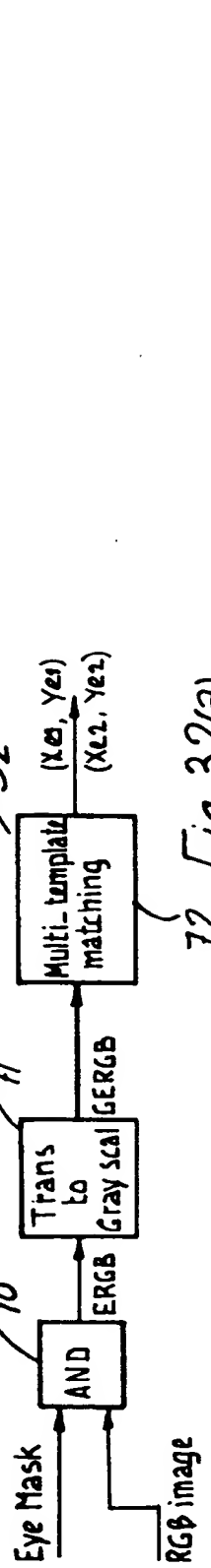


Fig. 32(a)

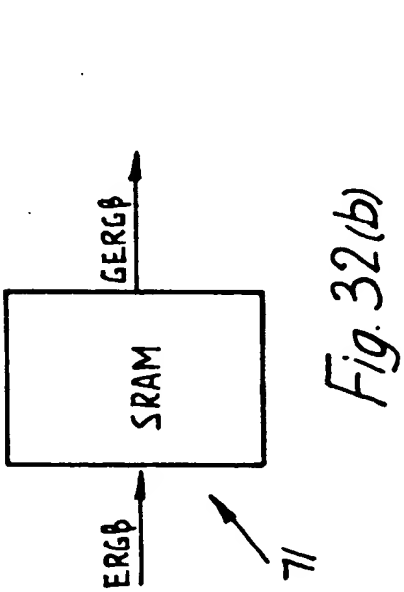


Fig. 32(b)

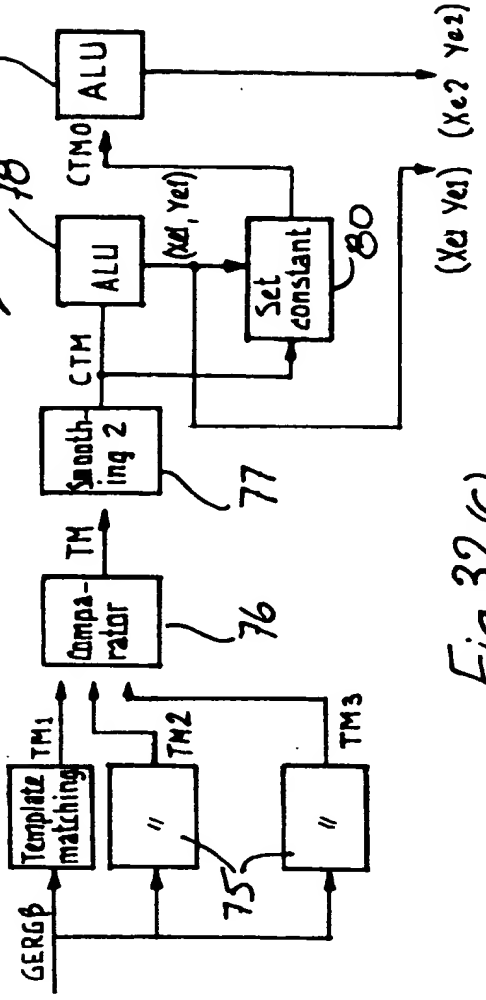


Fig. 32(c)

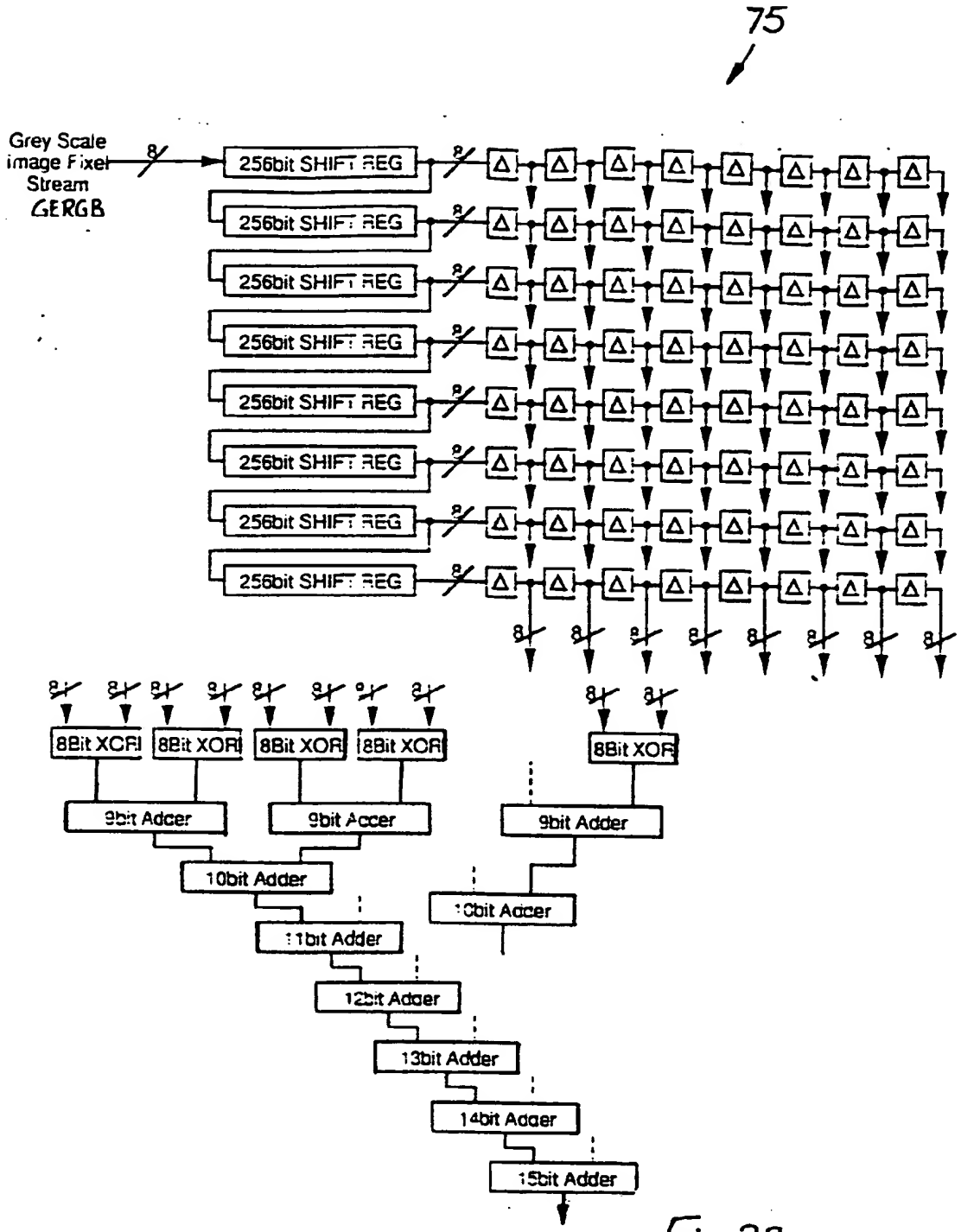
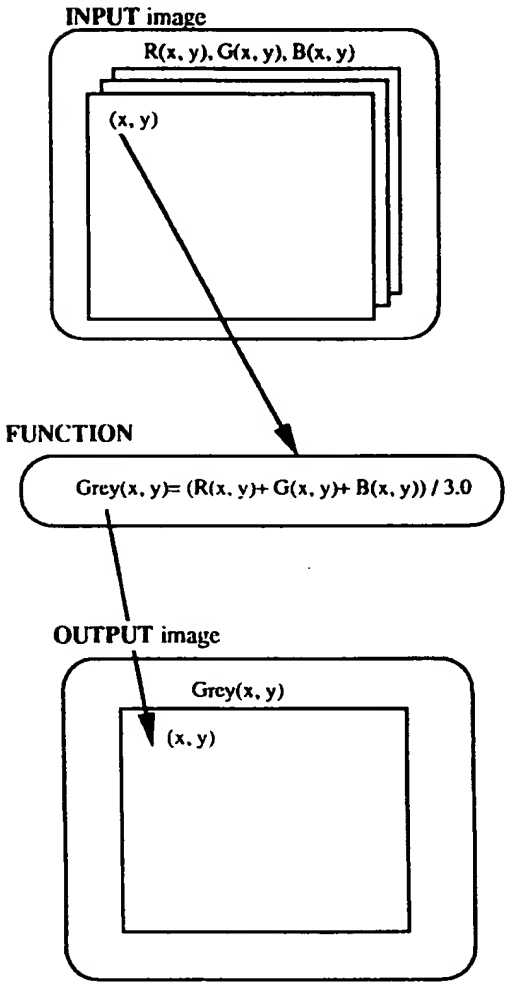

75
Grey Scale
image Pixel
Stream
GERGB
8
256bit SHIFT REG
256bit SHIFT REG
256bit SHIFT REG
256bit SHIFT REG
256bit SHIFT REG
256bit SHIFT REG
256bit SHIFT REG
256bit SHIFT REG
8Bit XOR
8Bit XOR
8Bit XOR
8Bit XOR
8Bit XOR
9bit Adder
9bit Adder
9bit Adder
10bit Adder
10bit Adder
11bit Adder
12bit Adder
13bit Adder
14bit Adder
15bit Adder

Fig.33

Transformation to grey scale



33(a)

Fig. 34

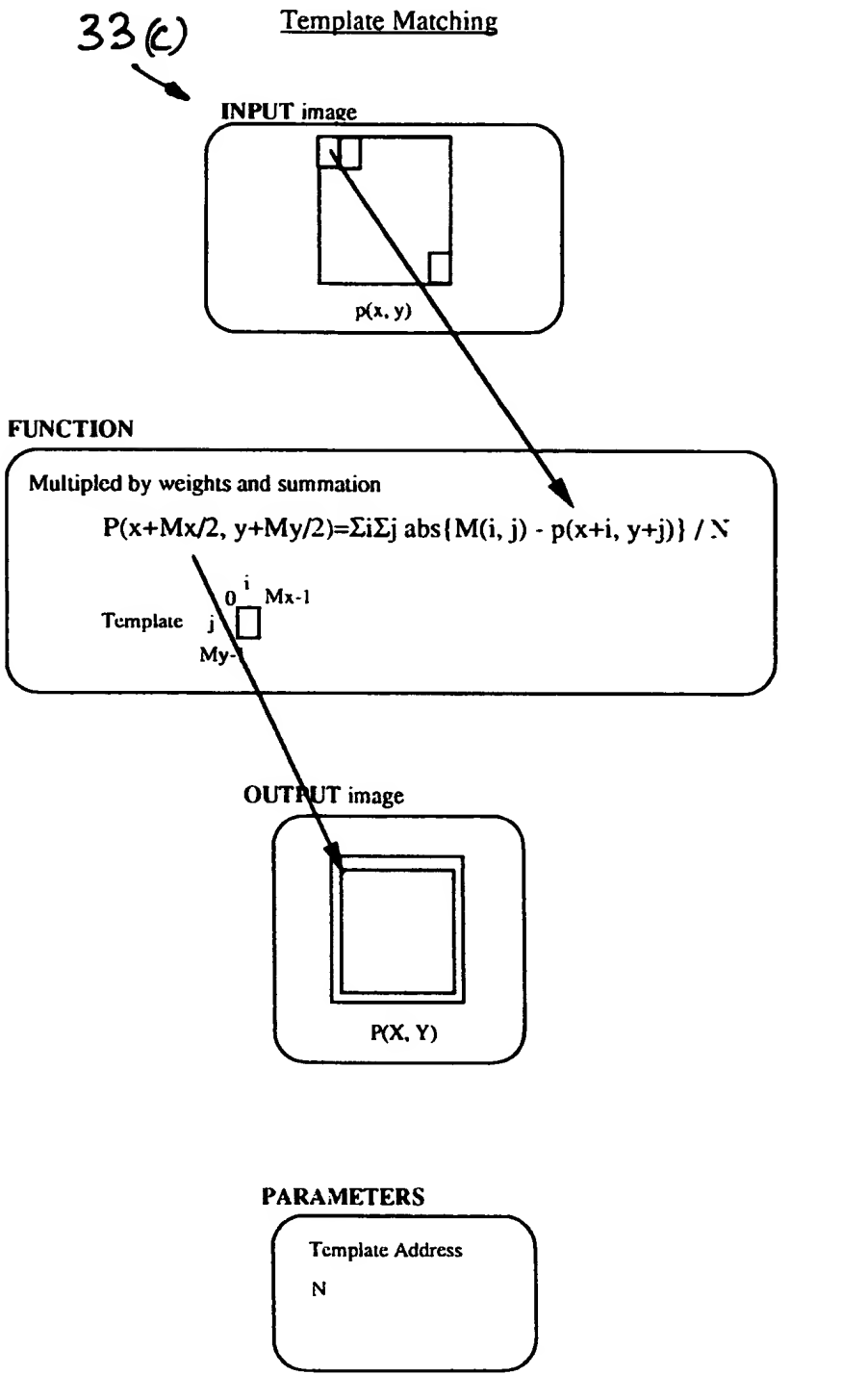

33(c)
Template Matching
INPUT image
p(x, y)
FUNCTION
Multipled by weights and summation
P(x+Mx/2, y+My/2)=ΣiΣj abs{M(i, j) - p(x+i, y+j)} / N
Template
0
i
Mx-1
j
My-1
OUTPUT image
P(X, Y)
PARAMETERS
Template Address
N

Fig.35

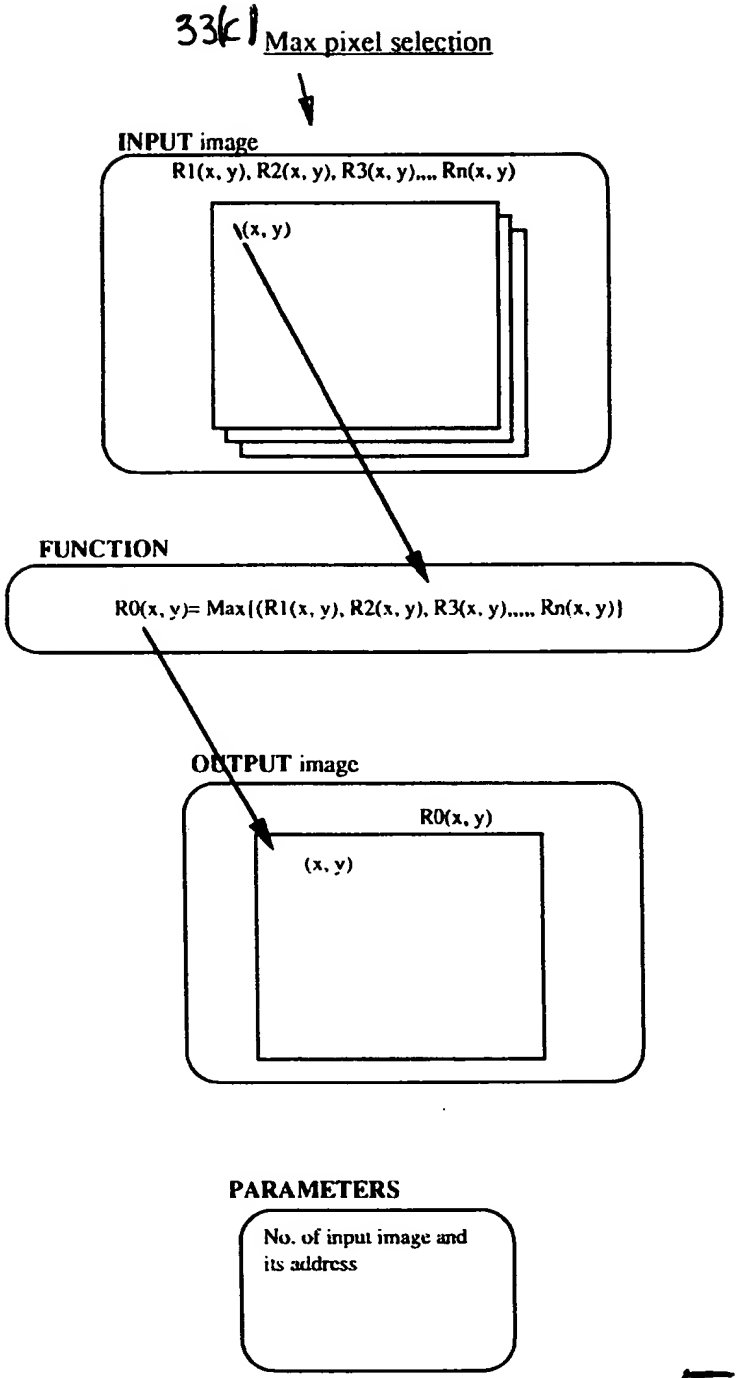

3361 Max pixel selection
INPUT image
R1(x, y), R2(x, y), R3(x, y),... Rn(x, y)
(x, y)
FUNCTION
R0(x, y)= Max{(R1(x, y), R2(x, y), R3(x, y),..... Rn(x, y)}
OUTPUT image
R0(x, y)
(x, y)
PARAMETERS
No. of input image and its address

Fig. 36

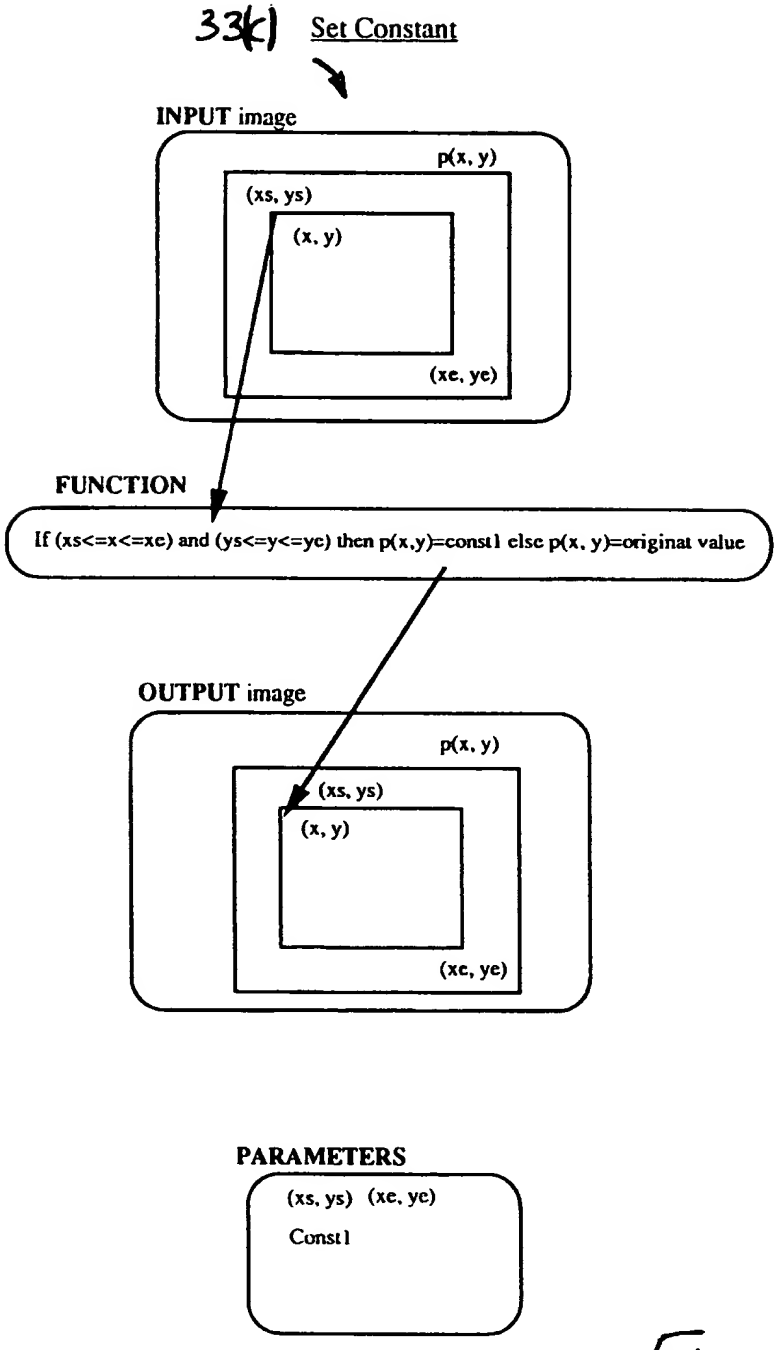

331
Set Constant
INPUT image
p(x, y)
(xs, ys)
(x, y)
(xe, ye)
FUNCTION
If (xs<=x<=xe) and (ys<=y<=ye) then p(x,y)=const1 else p(x, y)=originat value
OUTPUT image
p(x, y)
(xs, ys)
(x, y)
(xe, ye)
PARAMETERS
(xs, ys) (xe, ye)
Const1

Fig. 37

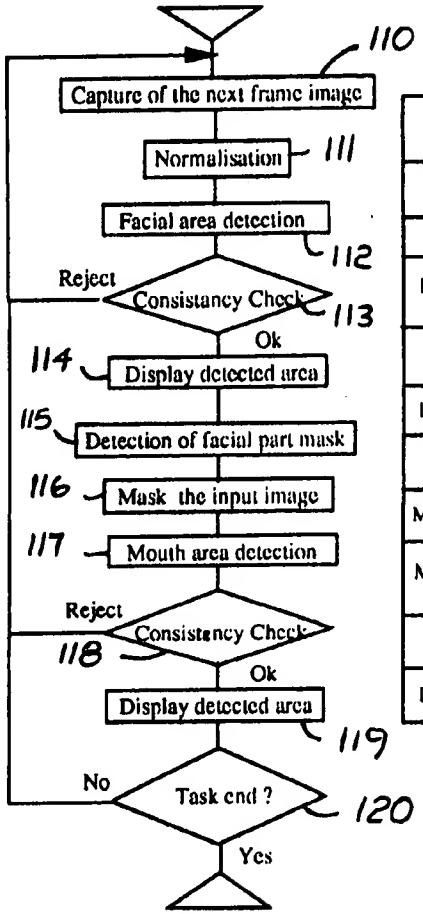


Fig.39

Processing name	Input	Output
Capture of the next frame image		Input RGB image
Normalisation	Input RGB image	RGB image
Facial area detection	RGB image	Position: (Xsf, Ysf) (Xef, Yef) Area: Af
Consistency Check	Position: (Xsf, Ysf) (Xef, Yef) Area: Af	Ok / Reject
Display detected area	Position: (Xsf, Ysf) (Xef, Yef)	Square box on monitor
Detection of facial part mask	BFimage	MouthMask EyesMask
Mask the input image	RGB image MouthMask	MRGB image
Mouth area detection	MRGB image Histogram template	Position: (Xsm, Ysm) (Xem, Yem) Area: Am
Consistancy Check	Position: (Xsm, Ysm) (Xem, Yem) Area: Am	Ok / Reject
Display detected area	Position: (Xsm, Ysm) (Xem, Yem) Area: Am	

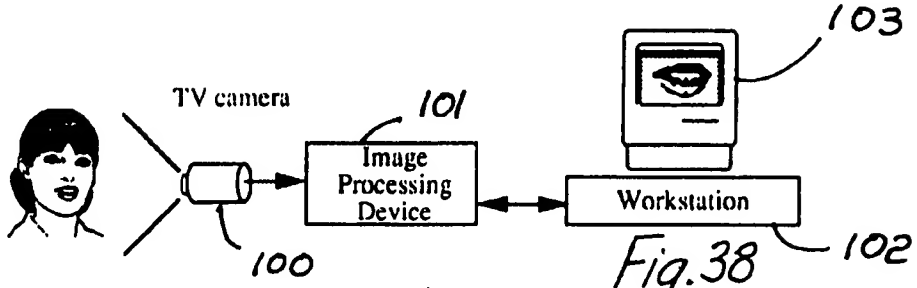


Fig.38

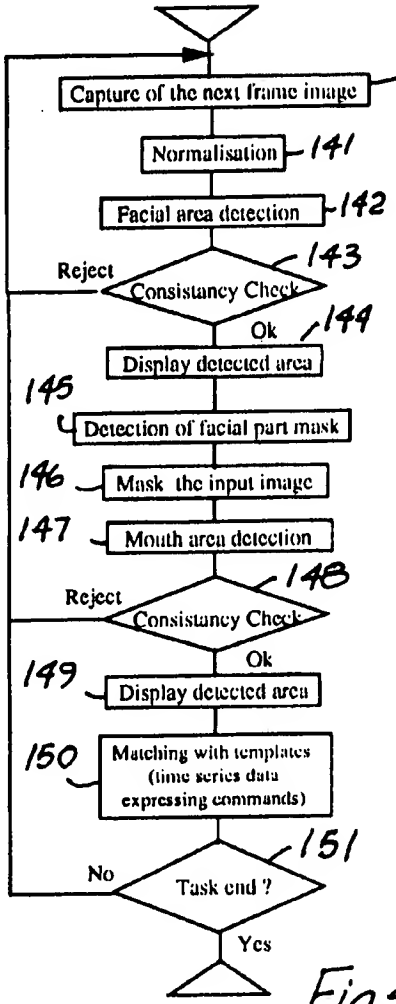


Fig.41

Processing name	Input	Output
Capture of the next frame image		Input RGB image
Normalisation	Input RGB image	RGB image
Facial area detection	RGB image	Position: (Xsf, Ysf) (Xef, Yef) Area: Af
Consistancy Check	Position: (Xsf, Ysf) (Xef, Yef) Area: Af	Ok / Reject
Display detected area	Position: (Xsf, Ysf) (Xef, Yef)	Square box on monitor
Detection of facial part mask	BFimage	MouthMask EyesMask
Mask the input image	RGB image MouthMask	MRGB image
Mouth area detection	MRGB image Histogram template	Position: (Xsm, Ysm) (Xem, Yem) Area: Am
Consistancy Check	Position: (Xsm, Ysm) (Xem, Yem) Area: Am	Ok / Reject
Display detected area	Position: (Xsm, Ysm) (Xem, Yem) Area: Am	
Matching with templates (time series data expressing commands)	Position: (Xsm, Ysm) (Xem, Yem) Area: Am	Command

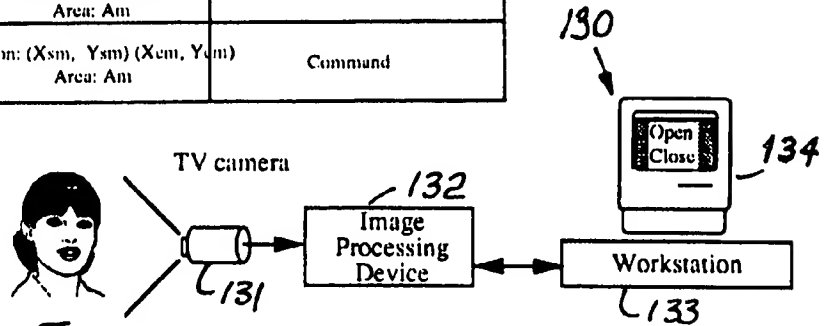


Fig.40